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LIVE SCIENCE

NEWS

- ▶ Pizza physics
- ▶ Glacier flour
- ▶ Schadenfreude

THE LATEST REVIEWS & TECH ADVICE FROM...

techradar

REVIEWS

- ▶ iPhone XS Max
- ▶ Fitbit Charge 3
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HOW IT WORKS

THE MAGAZINE THAT FEEDS MINDS



WILDLIFE WARRIORS
PROTECTING EARTH'S MOST VULNERABLE SPECIES



WHAT IF...

...ALL THE VOLCANOES ERUPTED AT ONCE?

**WHAT IF...
YOU FELL INTO A**

BLACK HOLE?



WHAT IF...

...ANTIBIOTICS STOPPED WORKING?

WHAT IF...

...WE MADE WASPS EXTINCT?



**+
INSIDE A CHOCOLATE FACTORY**

**PLUS MORE AMAZING ANSWERS
TO CURIOUS QUESTIONS**



DAREDEVIL STUNTS

How adrenaline junkies perform death-defying feats



**INSIDE THE
iPhone XS MAX**

Discover the tech that powers Apple's largest iPhone ever



+ ALIEN MOONS HOW IS TINSEL MADE? DOGSLEDS SNOWFLAKE CHEMISTRY RAINBOW MOUNTAIN

MESOZOOIC



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Science is all about curiosity. By asking questions about the world around us we increase our understanding of the universe and our place within it. Sometimes even the questions we think are silly prove to be valuable thought experiments that teach us something new. This month we seek to answer some of your curious questions, from the purely hypothetical (*what if you fell into a black*

hole?) to some more urgent concerns (*what if all our antibiotics stop working?*)

Also in this issue, we're getting festive with snowflake chemistry, reindeer anatomy, tinsel, chocolate factories, teddy bears and Christmas markets. Plus find out how to make your own decorative wreath in our How To on page 94. Enjoy the issue – and happy holidays!

Jackie **Jackie Snowden**
Editor



"The real answer to saving the planet's wildlife is through education and research..."

Wildlife warriors, page 34

Meet the team...



Charlie G
Production Editor

How many popes can you fit in a Ford D-series? 16! OK, forget the jokes and head to page 68 to learn about the Vatican (and Popemobiles).



Baljeet
Research Editor

Could the icy moons of Jupiter and Saturn hold the key to alien life in subsurface oceans? Find out more on page 58.



Charlie E
Staff Writer

This month we go behind the scenes at Lilongwe National Park to learn how wildlife rescue, rehab and research is saving Malawi's animals.



Scott
Staff Writer

As the doors of advent calendars swing open we take a closer look at how the chocolatey treats behind them are made on page 48.



Duncan
Senior Art Editor

Reading the What If...? feature got me wondering – what would life have been like if *Jaws* had never been filmed? It doesn't bear thinking about!

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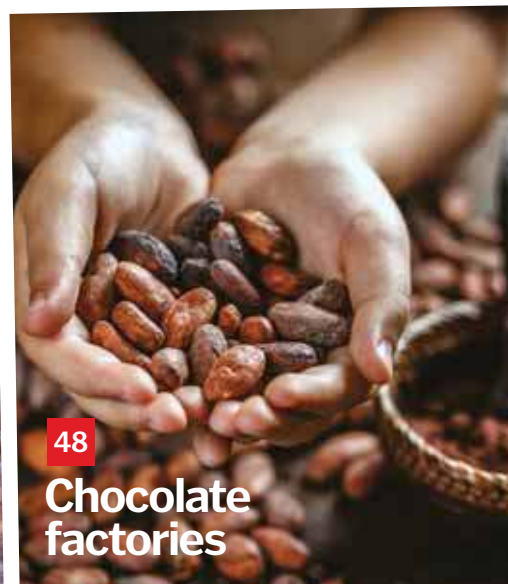
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MEET THIS ISSUE'S EXPERTS...



James Horton
Former **HIW** member James is a biochemist and biotechnologist. He is currently doing a PhD in machine learning and evolutionary theory.



Jo Stass
Jo has been a writer and editor for over six years. She is particularly interested in the natural world and technological innovations.



Jodie Tyley
The former Editor of **HIW** and **All About History** has tackled many topics in her career, from science fiction to science fact and Henry VIII to honey badgers.



Jonathan O'Callaghan
With a background in astrophysics, former **HIW** and **All About Space** journalist Jonathan enjoys delving into the wonders of space.



Laura Mears
Biomedical scientist Laura escaped the lab to write about science and is now working towards her PhD in computational evolution.



Lee Cavendish
Avid stargazer Lee writes for our sister magazine, **All About Space**, and has a degree in observational astronomy.



Stephen Ashby
Stephen has been a writer and editor for over seven years. He is endlessly intrigued by technology and Earth science.



Steve Wright
Steve has worked as an editor on many publications. He enjoys looking to the past, having also written for **All About History** and **History Of War**.

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Tim Williamson
History Of War Editor Tim has a passion for all things military but studies and writes about a range of historical eras.



Tom Lean
Tom is a historian of science at the British Library working on oral history projects. His first book, *Electronic Dreams*, was published in 2016.



Victoria Williams
Evolutionary biologist and *World of Animals* writer Vicky is fascinated by the natural world and happiest when she's outdoors.



SUBSCRIBE NOW!
GO TO PAGE 46 FOR GREAT DEALS

The 1914 Christmas truce

WW1 soldiers enjoying a game of football during their free time away from the trenches. On Christmas Day 1914 several unofficial truces were held across the Western Front. Soldiers from both sides met in No Man's Land, where they exchanged gifts, took photos, played football and tended to the dead or wounded.









Snug and smug

Even in sub-zero temperatures, the Arctic fox's thick, dense winter coat helps keep its body toasty. It has some of the warmest fur in the animal kingdom and won't even begin to shiver unless the temperature drops to around -70°C .

Inside the Icehotel

The world's first hotel built entirely out of ice and snow was founded in 1989 and has provided a unique experience for visitors ever since. Located in the Swedish village of Jukkasjärvi, the hotel melts each summer and is rebuilt every winter.





Kepler the planet hunter retires

The space telescope ends its scientific operations after nearly a decade of discoveries

On 30 October 2018 NASA announced the retirement of its Kepler Space Telescope after it ran out of fuel.

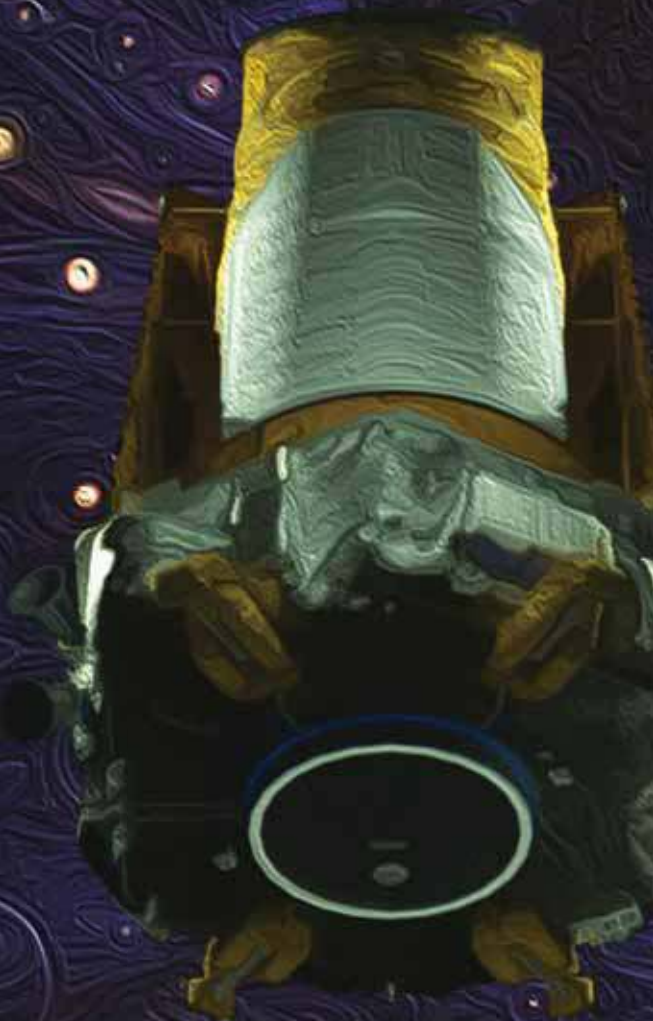
During its two missions – conducted over the course of nine years and seven months – Kepler found over 2,660 confirmed exoplanets, observed over 530,500 stars, documented over 60 supernovae and collected over 670 gigabytes of data.

Kepler was NASA's first dedicated planet-hunting mission, and the data that it has collected has revolutionised our understanding of the Milky Way. William Borucki, Kepler's founding principal investigator (now retired), explains.

"When we started conceiving this mission 35 years ago we didn't know of a single planet outside our Solar System. Now that we know planets are everywhere, Kepler has set us on a new course that's full of promise for future generations to explore our galaxy."

It is hoped that the Transiting Exoplanet Survey Satellite (TESS), which launched on 18 April 2018, will build upon Kepler's huge success. TESS will be monitoring an area of sky 400-times greater than that covered by Kepler, but it will be focusing on 200,000 of the brightest stars in our galactic neighbourhood in its search for thousands of new alien worlds.

NASA released this artwork in the style of Vincent van Gogh's *The Starry Night* to commemorate the Kepler mission's achievements



KEPLER'S GREATEST HITS

What has Kepler taught us about the Milky Way?

There are more planets than stars

Just a few decades ago we didn't know of any planets beyond those in our Solar System. We now know that almost every star in the galaxy is orbited by a planet or, in most cases, multiple planets.

Small planets are common

Based on Kepler data, it's estimated that between 20 and 50 per cent of the stars visible to us are likely to have small, Earth-sized worlds orbiting in their habitable zones.

Exoplanets are varied

A diverse range of exoplanets have been discovered during Kepler's missions. The most common types of planets in our galaxy are somewhere between the size of Earth and Neptune – something that does not exist anywhere in our Solar System.

Many systems are compact

Many exoplanets orbit their parent stars closely, unlike in our Solar System. It's not clear yet whether they form this close or whether they have migrated in.

Secrets of stars

Kepler studied over 500,000 stars during its lifetime. These observations have helped us understand the basic properties of exoplanets orbiting them and have even captured the beginnings of supernova explosions.



Kepler has run out of fuel after over nine years in deep space and will be retired in its current orbit safely away from Earth

SCIENCE

Llamas could help us beat flu

Their blood contains tiny antibodies that are more efficient at attacking viruses

The influenza virus infects millions of people every year and can cause as many as 650,000 deaths globally. The virus constantly mutates, changing its structure so it can evade our bodies' natural defences as well as the vaccines we use to help boost our natural immunity. This is what makes it so hard to eradicate the flu and why new vaccines are required each year.

However, scientists have discovered an unlikely new weapon against the shape-shifting virus – llama antibodies. Antibodies are small proteins produced by the immune system that bind to the proteins on the surface of viruses to neutralise them. Human antibodies only bind to the tips of the virus' surface proteins – parts that can be changed easily through mutations. But llama

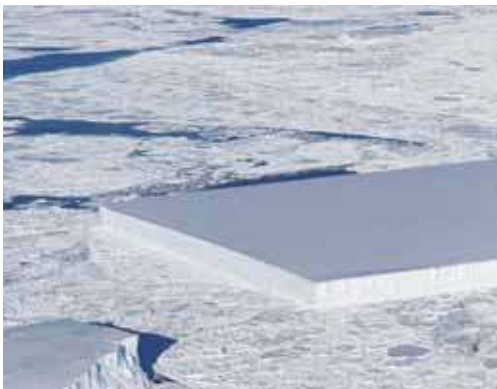


antibodies are much smaller than ours and can bind to parts of the virus that do not change. The researchers isolated the most effective antibodies from llama blood and used them to create a synthetic version that mimicked each of them.

The synthesised antibodies were tested on mice infected with flu. Out of the 60 different strains of virus tested, only one wasn't neutralised. The team will now be running

more studies before the therapy can be tested in humans, but if it works it could protect people from both seasonal flu and potential pandemics in future.

"Llama antibodies bind to parts of the virus that do not change"



ENVIRONMENT

Rectangular icebergs spotted

Scientists on NASA's Operation IceBridge aerial survey of polar ice spotted two unusually angular icebergs while flying over Antarctica near the Larsen C ice shelf. Relatively straight edges are not uncommon on icebergs, but the scientists had never seen such rectangular examples before.



HISTORY

Da Vinci's artistic eye explained?

Analysis of Leonardo da Vinci's paintings and sculptures suggests that he suffered from exotropia, a disorder that causes one eye to turn outward slightly. It is thought that the condition may have helped him switch between 3D and 2D vision when observing his subject and painting on the flat canvas.



TRANSPORT

China opens longest sea crossing

The 55-kilometre-long Hong Kong-Zhuhai-Macau Bridge is now open after nine years and around \$20 billion (approximately £15 billion) of construction. The bridge and tunnel system now connects the autonomous territories of Hong Kong and Macau to the city of Zhuhai of mainland China.

SCIENCE

Probiotics and antibiotics form a killer combo

The two-pronged attack has been found to help eradicate drug-resistant bacteria

Researchers from MIT managed to eradicate two strains of superbug that often infect wounds by using probiotics – beneficial bacteria found in our bodies – at the same time as delivering antibiotic drugs.

Probiotics can help fight bacteria by producing compounds that kill them, while others outcompete the pathogenic bacteria for nutrients.

Probiotics usually struggle to fight off all the different pathogenic strains that infect wounds, but combining their use with antibiotics can be tricky as the drugs would also kill the good bacteria. The MIT team overcame this key problem by encapsulating the probiotics in an alginate capsule to protect them from the antibiotics' effects.

During tests on the superbug MRSA, this combined approach wiped out all the pathogenic bacteria in the dish

TECHNOLOGY

Screen time could affect surgery students' dexterity

Concerns have been raised about a decline in the hands-on skills of young people

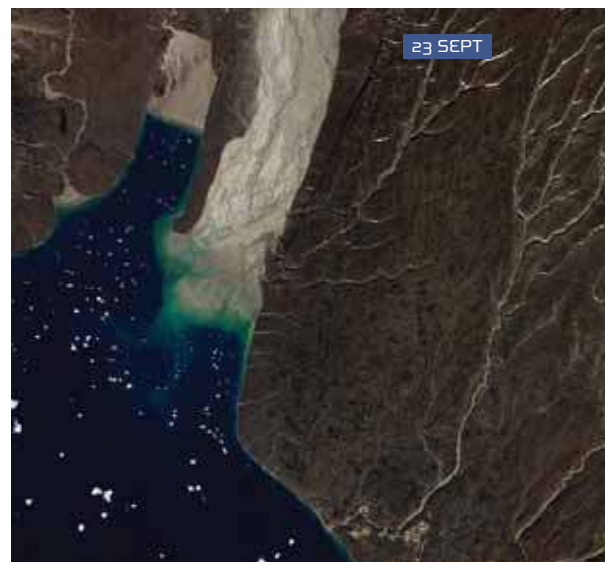
Surgery professor Roger Kneebone from Imperial College London has described how new students seem to struggle with practical tasks such as threading a needle and sewing – crucial skills for surgeons. The worrying decline in manual dexterity may be related to our increased dependence on touchscreen technology rather than learning how to use our hands through basic craft skills.

"It is a concern of mine and my scientific colleagues that whereas in the past you could make the assumption that students would leave school able to do certain practical things – cutting things out, making things – that is no longer the case," explained Professor Kneebone. "A lot of things are reduced to swiping on a two-dimensional flat screen... We have students who have very high exam grades but lack tactile general knowledge."

Professor Kneebone and others are calling for more well-rounded school curricula that supports creative subjects where these vital skills can be developed



A large plume of 'glacier flour' blew off Greenland on 29 September



PLANET EARTH

Glaciers created a huge 'flour' dust storm in Greenland

Words by **Rafi Letzter**

If you're in Greenland and a strange cloud darkens the sky, that cloud might be made up of something scientists call 'glacier flour'.

Researchers speculated about glacier flour dust storms in Greenland for a long time according to NASA, but it took until this September for investigators to spot a massive plume of the elusive dust forming 130 kilometres northwest of the village of Ittoqqortoormiit. Glacier flour is a fine dust created when glaciers pulverise rocks, NASA wrote. While satellites had occasionally spotted smaller storms of the stuff, this one was "by far the largest".

"We have seen a few examples of small dust events before this one, but they are quite difficult

to spot with satellites because of cloud cover," Joanna Bullard, a professor of physical geography at Loughborough University in the UK, said in a NASA statement. "When dust events do happen, field data from Iceland and west Greenland indicate that they rarely last longer than two days."

The flour storm formed when a summer floodplain in the region dried out with late September's colder weather, leaving behind a large deposit of sediment carried south from more northern glaciers. NASA satellites watched the floodplain become greyer and greyer as it dried out, then saw the plume form when strong winds swept through the area on 29 September.

According to NASA, storms like this are interesting because researchers just don't know that much about them or how they affect the climate. While large dust storms found closer to the equator have known climate impacts, the role of glacial flour remains a mystery. Further research into this floury enigmas will be required before their impact is understood.

"Investigators spotted a massive plume of the elusive dust forming"

STRANGE NEWS

Italian physicists wrote a ‘perfect pizza’ equation, because not all heroes wear capes

Words by **Brandon Specktor**

If you’d like to eat the world’s most scientifically perfect pizza, you have two options: one, fly to Rome and order a margherita pizza fresh from the brick oven; or two, solve a long thermodynamic equation to simulate that glorious Italian pizza in your electric oven at home. That’s the basic premise of a new paper titled *The physics of baking good pizza*, published earlier this year in the preprint journal *arXiv*.

The secret to an authentic pizza is the physics of the brick oven. With a wood fire burning in one corner, heat radiates uniformly through the curved walls and stone floor of the oven, ensuring an even bake on all sides of the pizza. Under ideal conditions, the authors wrote, a single margherita could be baked to perfection in precisely two minutes in a brick oven heated to 330 degrees Celsius. When additional toppings require additional bake time, some pizzaiolos

may lift the pizza up with a wooden or aluminium spade for an additional 30 seconds or so “in order to expose the pizza to just heat irradiation” and prevent a toasty bottom, the authors wrote.

Don’t own a brick oven at home, because you’re a normal person? The authors have helpfully described how to simulate that pizza a la Roma perfection in a standard electric oven.

Using a long thermodynamic equation, the authors determined that a pizza cooked in an electric oven could meet similar conditions to a Roman brick oven by turning the heat down to 230 degrees Celsius for 170 seconds. Crucially, the authors noted, aspiring pizzaiolos cooking toppings with higher water content (basically any additional vegetables) may need to leave their pizzas in the oven longer, as the pizza will return more heat to the oven via evaporation.

The study was conducted by physicists Andrey Varlamov and Andreas Glatz and food anthropologist Sergio Grasso



While the authors of the study concluded that your homemade pizza will probably never be as perfect as a fresh, firebrick pizza, physics can still help you to take a step in the right direction towards a tastier offering at dinner time.

CULTURE

Schadenfreude may come in three flavours – some meaner than others

Words by **Stephanie Pappas**

If you’ve ever revelled in the misfortune of another, you’ve experienced what the Germans call ‘schadenfreude’. But which kind did you experience?

A new paper argues that there are three subtypes of schadenfreude, some of which might seem more morally defensible than others. People can experience glee in others’ pain out of a genuine desire for justice, researchers wrote in an upcoming issue of the journal *New Ideas in Psychology*, which is arguably understandable. However, others can be motivated by us-versus-them dynamics or even by petty jealousies.

What ties all these subtypes together, said lead study author Shensheng Wang – a graduate student in psychology at Emory University in Atlanta, US – is a common thread of dehumanisation. “When we fail to perceive others as humans, when we dehumanise others, we cut off the link

Schadenfreude is pervasive among people in all settings, from political rivalries to sports



between us and the person who experiences a misfortune,” Wang explained.

Wang first became interested in the concept of schadenfreude a few years ago when he was researching how children experience envy and competition. Schadenfreude had come up in earlier research by other scientists, Wang said, but he found

that researchers tended to define it in different ways. He argued these scholars are focusing on different types of schadenfreude, each with its own motivation.

The first motivation, social justice, links to people’s desires for fairness and the punishment of wrongdoers, Wang said. The second type of motivation, aggression, draws a line between ‘us’ and ‘them’ and solidifies the social identity of the person feeling the schadenfreude as a member of the ‘in group’. Then there is the third and final motivation, rivalry, which occurs when the person feeling schadenfreude is motivated by personal envy and spite.

So far, there isn’t a lot of research attempting to discern schadenfreude subtypes, Wang said, adding that he hopes the new paper will spur more studies.

The XS Max features improved splash and water resistance



Head to page 54 to check out a teardown of the iPhone XS Max



REVIEW

iPhone XS Max verdict

Words by **Gareth Beavis**

The iPhone XS Max (pronounced 'ten S max') is the biggest smartphone Apple has ever made. With a 6.5-inch display, hardly any screen bezel and the now-iconic screen notch, it is certainly a dominating presence in the hand.

It also dominates the pocket, both in terms of size and price. As well as being the biggest, the iPhone XS Max is also the most expensive iPhone to date, with Apple delivering a handset with a screen size that rivals the most premium of Android flagships. This is a bold statement from a firm that has, up until last year with the introduction of the 5.8-inch iPhone X, resisted the urge to push the screen size envelope to the same scale as its Android rivals.

This is the first time Apple has really pushed its screen size boundaries, and by offering a huge 6.5-inch display it's made its smartphone line attractive to a new segment of customers.

The extra screen real estate will be music to the ears of gamers, while HDR support will please those addicted to Netflix and Amazon Prime Video, and while the iPhone XS Max screen isn't the best on the market, it is the best screen on an iPhone, ever.

Apple's updates to the rear cameras (over the iPhone X) are minimal, but the ability to adjust

the background blur on portrait shots and the improved Smart HDR mode offer greater flexibility and ultimately better image quality, and while the iPhone XS Max is a big phone, it's also impressively compact. It's a touch smaller than the iPhone 8 Plus but has a much larger display (6.5 vs 5.5 inches). It will still dominate your hand, but it's not as unwieldy as you might expect for a phone with a screen this size.

Ultimately though, it's the iPhone XS Max's price that will likely be the sticking point for many potential buyers. There's simply no getting away from the fact that this is a very, very expensive smartphone.

The iPhone XS offers everything the Max does bar the 6.5-inch display, for less, while the new iPhone XR has a 6.1-inch display and even lower price tag, although it does make compromises in other areas.

WHO'S IT FOR?

The iPhone XS Max is designed for those looking for the absolute pinnacle of Apple's smartphone line. The firm has never offered a handset with a screen as big as the one on the iPhone XS Max, and that alone will have power users, gamers and video streamers champing at the bit to get their hands on it.

You'll need the funds to bankroll your XS Max investment though, so if you're on a tight budget you may want to consider the more affordable iPhone XR. However, if money is no object and you want the best screen Apple has ever put on an iPhone, the XS Max is your phone.

SHOULD I BUY IT?

The iPhone XS Max is a premium smartphone that looks and feels the part. Sure it's expensive, but if your budget stretches you're unlikely to be disappointed with what you get in return. As we've already mentioned, you won't find a better screen on an iPhone, and there's a huge amount of power inside the handset, which should ensure performance stays high throughout its lifetime.

- 64GB model: £1,099 / \$1,099
- 256GB model: £1,249 / \$1,249
- 512GB model: £1,449 / \$1,449

- ⊕ Screen great for gaming & movies. Camera is a strong offering.
- ⊖ Price: most expensive iPhone ever. Size can make it tricky to handle.



HEAD-TO-HEAD

PS4 Pro vs Xbox One X

Words by Nick Pino

Gamers haven't had an easy choice to make these last five years – both the Xbox One and PS4 were two of the most competent consoles ever seen. Both had a lot going for them – new games, higher specs and a smattering of new features – giving gamers a clear reason to upgrade from the Xbox 360 and PS3.

These sequels, the Xbox One X and PS4 Pro, are even more powerful than the originals, challenging gamers to pick between two outstanding consoles.

In terms of pure power, Xbox One X wins. Its memory bandwidth, RAM, CPU and GPU all outperform PS4 Pro, and with *Middle-earth: Shadow of War* we've already seen evidence this can have a graphical impact.

However, not every developer will use the Xbox One X's power to its full potential, and at the moment it seems likely there will be a lot of parity across the two for some time.

In terms of future-proofing, the Xbox One X's power makes it your best bet, but a distinct lack of exciting first-party games may make the PS4 Pro more appealing. After all, what does draw distance matter if it means missing out on *God of War*?

That said, outside of gaming content, the Xbox One X boasts an Ultra-HD Blu-ray player and fantastic backwards compatibility that will reduce the disruption you'd usually expect from mid-generational upgrades. The Xbox One X also has the benefit of being Microsoft's smallest console ever. However, there is the matter of price to consider. The Xbox One X is £100 / \$100 more expensive than the PS4 Pro, which may give some players pause.

■ Xbox One X: £449 / \$499

■ PS4 Pro: £349 / \$399



www.howitworksdaily.com

REVIEW

Fitbit Charge 3

Words by Lee Bell

In August 2018, Fitbit updated its Charge line-up with the third generation device, the Charge 3, offering exercise, sleep and heart rate tracking in a more lightweight design, with a larger display and waterproofing.

While its feature set isn't in the same league as, say, that of its older brother, the Fitbit Versa, the Fitbit Charge 3 offers many of the same features just in a more compact and lightweight design that is by no means earth-shatteringly beautiful but still looks the part.

It also does exactly what it says on the tin: tracking everyday workouts without promising you the world and not asking for it either when it comes to costs.

There's a nice and simple yet clear and bright display, a host of nifty smart notifications, contactless payment capabilities (for a little extra) and all the features Fitbit users will have come to know and love.

However, what makes it worth considering is that you can pick up some really great fitness tracking features, all wrapped up nicely in a well-designed app, for just under £130 / \$150, something that's hard to fault and also something many of Fitbit's competitors can't compete with.

WHO'S IT FOR?

The Fitbit Charge 3 is essentially for those that are into keeping active and want to keep on top of their exercise routine but aren't so much into working out that they'd consider themselves fitness fanatics.



Take, for instance, if you're an avid runner looking for a running watch – the Charge 3 just isn't for you. It's better suited to someone looking to track their daily step count and a bit of exercise every few days without the need for all the bells and whistles that something like the Fitbit Ionic will offer you.

SHOULD I BUY IT?

If you're after an activity tracker and consider yourself a moderate exerciser (working out twice or so a week) then the Fitbit Charge 3 is by far one of the best choices money can buy. However, Fitbit has a substantial range of wearables all aimed at different types of individuals, so we'd suggest doing some research. For instance, if you don't need swim tracking you could potentially instead opt for the Fitbit Alta HR.

■ £129.99 / \$149.95

⊕ Bigger screen / Lighter design / Completely waterproof.

⊖ No onboard GPS / Monochrome screen / Proprietary charger.

★★★★★



For more of the latest tech reviews and advice head to **techradar.com**

Christmas Gift Guide

Struggling to think of the perfect present? These six gifts are ideal for all science and tech fans

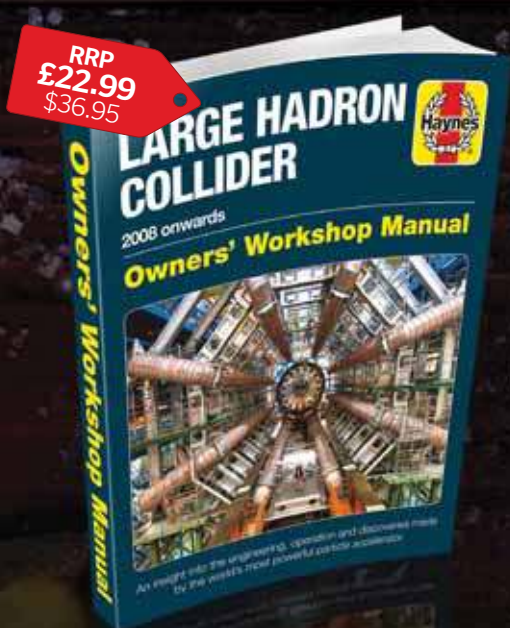
Haynes Large Hadron Collider Manual

haynes.co.uk

Here is another excellent example of Haynes demystifying a highly complex subject, in this case particle physics. The *Large Hadron Collider Manual* tells the story of how physicists are seeking answers to the universe's biggest questions using the world's largest particle smasher – the Large Hadron Collider – at the CERN laboratory on the Franco-Swiss border.

Beginning with the first tentative steps taken to build the machine, the digestible text – supported by colour photographs of the hardware involved, along with annotated schematic diagrams of the physics experiments – covers the particle accelerator's greatest discoveries from both the perspective of the writer and the scientists who work there.

Here is a full, comprehensive guide to the most famous, record-breaking physics experiment in the world, which continues to capture the public imagination as it provides new insight into the fundamental laws of nature.



QuickBuild RAF Red Arrows Hawk

airfix.com

Since 1965 the Red Arrows have been performing their thrilling manoeuvres to audiences all over the world, appearing in almost 5,000 displays in over 50 countries.

To join the Red Arrows display team candidates have to have completed a front line tour as a Royal Air Force pilot, have a minimum of 1,500 flying hours and be assessed as 'above average' in their current RAF flying role. A maximum of three new

pilots are chosen each year, so the pilots of the Red Arrows really are the best of the best!

The Red Arrows Hawk is a British icon, and you can recreate your own at home with an Airfix QuickBuild kit. QuickBuild kits give you the ability to recreate a wide variety of iconic aircraft, tanks and cars into brilliant scale models. No paint or glue is required, and the push-together brick system is also compatible with other plastic brick brands.

Face In Space

faceinspace.co.uk

If you're having problems finding a gift for someone who has everything, then The Face In Space team may be able to help. They can send your special message, photo, logo, or even a mince pie up into the atmosphere on a big weather balloon and film it on an HD video as it floats through the blackness of space with the curvature of the Earth as a backdrop. They are now taking bookings for flights in 2019.





OrbGaming Virtual Archer

geniegadgets.com

Unleash your inner Robin Hood with this fun gadget! Simply download the free app and attach your phone to the bow to get started. From target practice to battling dragons, you can shoot your way through a variety of immersive, 360-degree games and become an virtual archery ace in no time.

RRP
£27.95
approx \$35

RRP
£27.50
\$32.95



Motors & Generators

thamesandkosmos.com

With this kit you can carry out 25 different experiments for hours of fun learning about electronic circuits. Along the way you will also learn about gears, drive-trains and energy with a full-colour, 48-page manual to guide you through each experiment.

Powerball gyroscope

powerballs.com

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**WHAT IF...
YOU FELL INTO A**

BLACK HOLE?

**PLUS MORE AMAZING ANSWERS
TO CURIOUS QUESTIONS**

Words by **Laura Mears**

WHAT IF ANOTHER SUPERCONTINENT FORMED?



A new mountain range appears on the left while one plate sinks under another on the right

The tectonic plates that carry Earth's land masses are still moving beneath our feet

Earth's crust isn't solid; it's made of seven major and ten minor tectonic plates, which shift and slide over molten rock, crunching together or spreading apart. They move at around the same speed your fingernails grow, and throughout Earth's history they've taken many different forms. At several points, all Earth's landmasses have come together to form supercontinents, and traces in rock suggest that it might happen again.

Scientists aren't in total agreement about how the next supercontinent will look; it all depends on what happens to the tectonic plates that sit under the oceans. When oceanic plates collide with other plates subduction zones can emerge (one plate dips under the other and melts into the mantle). This is happening in the Atlantic, the Pacific and in the Arctic Circle, causing plates to shrink and shift.

Work by geophysicists at Yale University suggests that the Arctic Circle might be the location for the next supercontinent. When rock is molten, iron atoms pull into line with Earth's magnetic field. Then, as the rock hardens, their position fixes. This leaves a trace of the direction in which landmasses were facing when they formed, so as continents shift around we can see where they came from. By looking at these traces the team of scientists found that the centre of each supercontinent was around 90 degrees away from the centre of the last one. If the next one follows this pattern, it will surround what is now the Arctic Circle.



Earth's surface is a mosaic of sliding tectonic plates

"Tectonic plates move at around the same speed your fingernails grow"

The breakup of Pangaea

How did we get to the seven continents that we see on Earth today?



The last supercontinent

200 million years ago Earth's land was all part of the continent Pangaea and the sea was all one ocean, known as Panthalassa, Greek for 'all sea'.



Laurasia and Gondwanaland

Pangaea split in two 180 million years ago. Laurasia contained North America, Europe and Asia. Gondwanaland contained Antarctica, Australia and South America.



Today's continents emerge

Laurasia and Gondwanaland broke apart into the modern continents 130 million years ago.



Change continues

The Atlantic Ocean widens and the Pacific Ocean shrinks, forcing the continents apart.

5 FACTS ABOUT PREHISTORIC SUPERCONTINENTS

1 Pangaea
The last supercontinent existed just 280 million years ago. Reptiles had just emerged, a mass extinction was imminent, and dinosaurs were about to appear.

2 Rodinia
This supercontinent covered Earth around 1 billion years ago, supporting the first multi-celled life on our planet. Plants emerged first, and animals soon followed.

3 Nuna
Also known as Columbia, this supercontinent dates back around 1.8 billion years. At this point in Earth's history complex cells were just starting to emerge.

4 Kenorland
This supercontinent appeared around 2.4 billion years ago, around the time that oxygen levels started to rise in the atmosphere. Air became breathable, but it triggered an ice age.

5 Vaalbara
This supercontinent existed 3.1 billion years ago, just after photosynthesis started to fill the atmosphere with oxygen. Only two pieces remain, one in South Africa and one in Australia.



Q WHAT IF EARTH DIDN'T HAVE THE MOON?

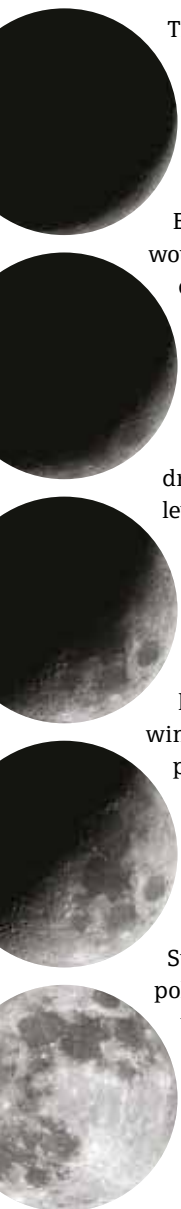
Our planet's lifeless companion helped to make our world habitable

The Moon appeared around 4.5 billion years ago when a chunk of rock the size of Mars smashed into our planet. It's only around a quarter of the size of Earth, but everything would change if it disappeared.

The gravitational pull of the Moon tugs on Earth's oceans, pulling them out into a bulge at the equator. Not only does this drive the tides and affect sea levels across the planet, it also slows down our rate of rotation. If the Moon disappeared, we'd speed up until we were spinning around every six hours, whipping up lethal winds of over 160 kilometres per hour!

The Moon also keeps us stable; without it, Earth's axis would tip every few million years. First, the equator would point at the Sun, then we'd slip and the poles would face our star. This would make the climate so unstable that life would struggle to adapt.

Ancient farmers used the light of the full Moon to work the fields at night



No-oxygen Earth

A few seconds without oxygen could spell the end of life as we know it

Hydrogen oceans

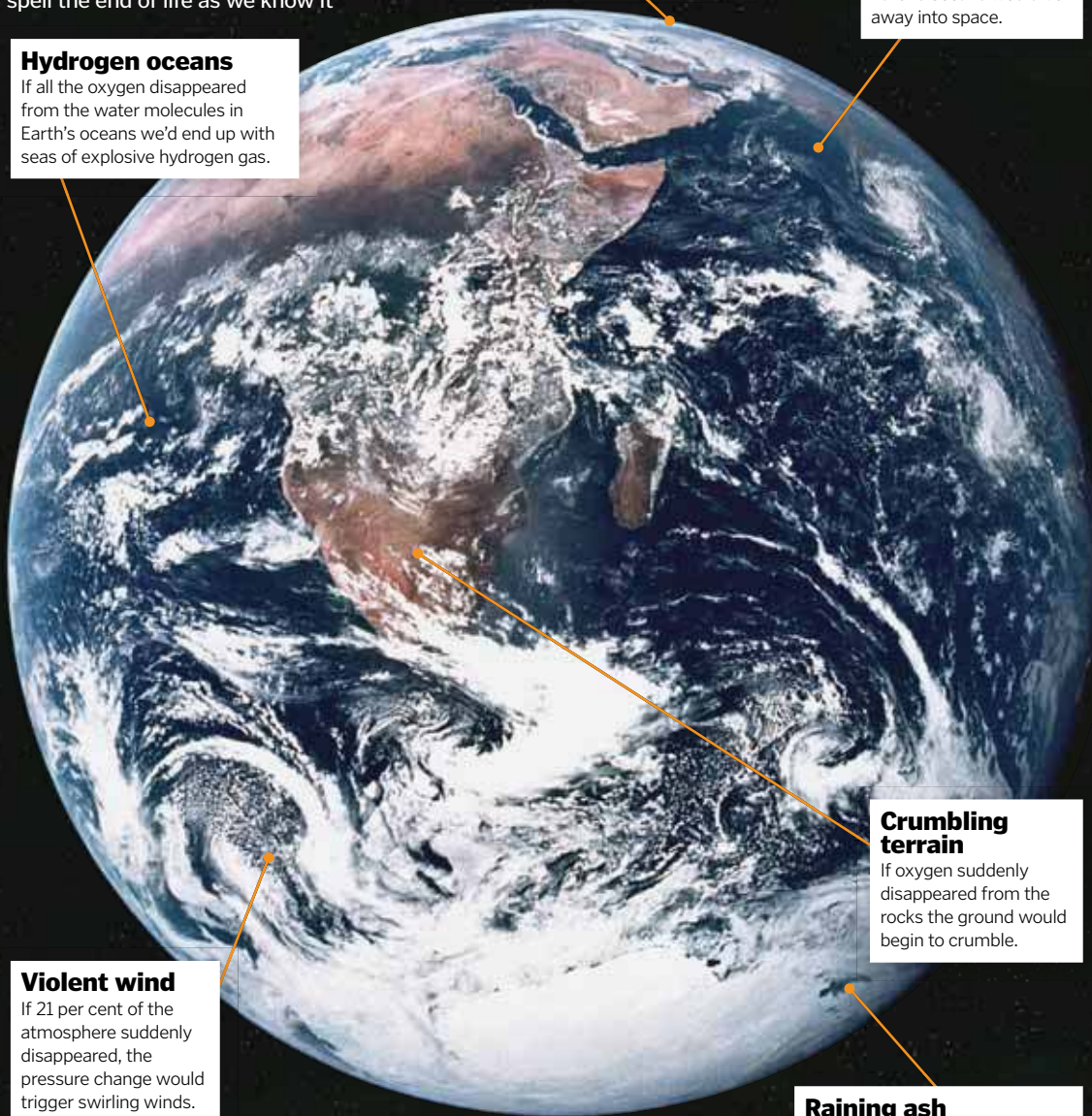
If all the oxygen disappeared from the water molecules in Earth's oceans we'd end up with seas of explosive hydrogen gas.

No sun-shield

The ozone layer (which is made from oxygen) would disappear, showering Earth in intense ultraviolet radiation.

Boiling away

Hydrogen is the smallest, lightest element, so Earth's oceans would boil away into space.



Violent wind

If 21 per cent of the atmosphere suddenly disappeared, the pressure change would trigger swirling winds.

Crumbling terrain

If oxygen suddenly disappeared from the rocks the ground would begin to crumble.

Raining ash

Carbon from carbon dioxide would drop out of the air, leaving an atmosphere of inert nitrogen.

Q WHAT IF OXYGEN DISAPPEARED FOR FIVE SECONDS?

"Around 21 per cent of Earth's atmosphere is oxygen"

We wouldn't suffocate but the world would be in chaos

If you've ever tried holding your breath, you'll know we can go a lot longer than five seconds without oxygen. But if oxygen disappeared the world would turn to chaos.

Around 21 per cent of Earth's atmosphere is oxygen, and without it atmospheric pressure would drop. Our ears would pop and we'd get

decompression sickness as the other gases inside our bodies expanded. Every fire would go out, combustion engines would stall, and cars, planes and trains would coast or crash. Plastic polymers would fall to pieces, rocks would crumble, and oxides would disappear, cold welding all metal surfaces together in an instant.

WHAT IF THE SUN WERE HALF AS BIG?

A smaller star might last longer, but Earth would be a very different planet

Earth sits in an orbit around the Sun called the habitable zone. This 'Goldilocks' region of stellar space is not too hot and not too cold, just right for liquid water to flow freely in Earth's lakes, rivers and oceans. The position of this zone depends on the size of our star, and if the Sun suddenly halved in mass everything would change.

The Sun is a G-dwarf star, also known as a yellow dwarf. It fuses hydrogen atoms together to make helium, generating a surface temperature of between 5,300 and 6,000 Kelvin (around 5,000 to 5,700 degrees Celsius). A star half its size would be an M-dwarf star, also known as a red dwarf, with a much lower temperature of between 2,500 and 4,000 Kelvin (2,200 to 3,700 degrees Celsius). To keep our water liquid around this kind of star we'd need to orbit much closer, and that would cause some problems.

Huddling close to a red dwarf star would generate strong tidal forces. This would slow Earth's spin, lengthening our days. It's possible that we'd decelerate so much that we'd become locked in one orientation, with one side of the planet always in daylight and the other in perpetual darkness. If this happened our water might freeze or boil away, leaving Earth barren and lifeless.

Our star in numbers

142mn km The inner edge of the Sun's habitable zone

150mn km Earth's distance from the Sun

4,500,000,000 years The Sun's age

5,000,000,000 The estimated number of years the Sun has left

8 mins How long it takes light to reach Earth from the Sun

450 KPS The speed of solar wind

960,000 The number of Earths that would fit inside the Sun

Supersize stars

Our Sun is puny compared to many other stars that we know of. Let's meet some of them...

RW Cephei

Size: 1,535 x Sun
Distance from Earth: 3,500 lightyears

VY Canis Majoris

Size: 1,420 x Sun
Distance from Earth: 3,900 lightyears

Mu Cephei

Size: 1,260 x Sun
Distance from Earth: 6,000 lightyears

KW Sagittarii

Size: 1,009 x Sun
Distance from Earth: 7,800 lightyears

Antares A

Size: 680 x Sun
Distance from Earth: 550 lightyears

V354 Cephei

Size: up to 1,520 x Sun
Distance from Earth: 9,000 lightyears

KY Cygni

Size: 1,420-2,850 x Sun
Distance from Earth: 5,000 lightyears

VV Cephei A

Size: 1,050 x Sun
Distance from Earth: 4,900 lightyears

Betelgeuse

Size: 950 x Sun
Distance from Earth: 643 lightyears

V838 Monocerotis

Size: 380 Sun
Distance from Earth: 6,100 lightyears

*Not to scale



Q WHAT IF PLASTIC WAS NEVER INVENTED?

The modern world just wouldn't work without this wonder material

There is plastic in your teabags, it makes your socks stretchy, and it stops the fat in your packet of crisps going rancid. It's used in life-saving medical technology, like syringes, catheters and incubators. It forms the circuit boards inside your phone, the insulation that wraps the wires in your house, and it makes planes light enough to fly. Without it, the modern world as we know it would not exist.

Plastic is one of the most versatile materials ever invented, but it's become so cheap we don't think twice about throwing it away. According to research from the University of California, we have made over 8 billion tons of plastic, and we have thrown three-quarters of it away. We sent 79 per cent to landfill, burnt 12 per cent and recycled nine per cent, all since the 1950s.

Unlike with organic waste, most bacteria simply won't touch plastic, so it doesn't matter how long we leave it, it will never biodegrade.



We make **150 million tons** of single-use plastic a year.

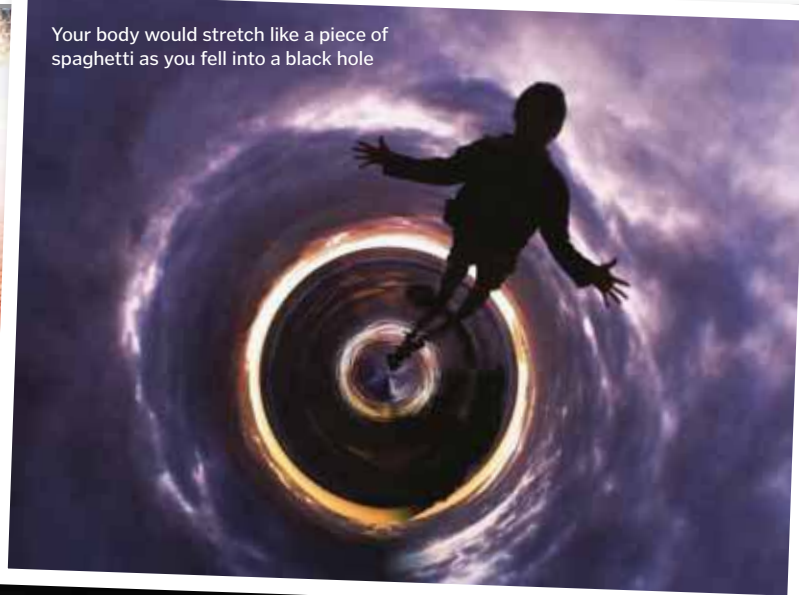
We buy **1 million** disposable plastic bottles a minute.

We use plastic bags for an average of just **15 minutes** before throwing them away.

It takes **450 years** for a plastic bottle to break down.

Each year **8 million tons** of plastic ends up in our oceans.

Your body would stretch like a piece of spaghetti as you fell into a black hole



Q WHAT IF YOU FELL INTO A BLACK HOLE?

Travelling into the singularity of one of these objects would be the one-way trip of a lifetime

A black hole has one of the strongest gravitational pulls of any object in the universe; get caught in its clutches and you're doomed. Beyond a point called the event horizon, space and time curve so extremely that even light cannot escape. Inside, matter crushes down to a single point, called a singularity. This black spot is completely invisible because light can't get out. Even so, you can see the effects from the outside.

If you got close to a black hole you would see light starting to bend, swirling around the central dark point like water going into a plughole. You'd start to move faster and faster as gravity tugged you in and, if you were travelling feet first, you'd see strange things happening to your body. Your feet, closer to the black hole than your head, would experience a stronger pull and your body would start to stretch. If the black hole were small, you'd rip apart, but if it were large, you'd carry on spinning.

When you crossed the event horizon everything would go dark, but you wouldn't have long to look around. You'd become part of the black hole, crushed to a speck with no chance of escape.

5 FACTS ABOUT BLACK HOLES

1 They really are supermassive
Stellar black holes are only around ten or 20 times more massive than the Sun. Supermassive black holes are millions of times more massive.

2 Galaxies spin around them
There may be a supermassive black hole in the middle of every large galaxy in the universe. All the stars orbit around the outside.

3 They burp
The NASA's Chandra X-ray Observatory revealed that black holes belch out streams of high-energy particles as they feast on gas from nearby stars.

4 They've never been photographed
We can't see black holes directly because no light can get out; we can only see space and light warping around them.

5 We orbit one
Sagittarius A* is a supermassive black hole at the centre of the Milky Way. Don't panic, it's 26,000 lightyears away.

Shielding the skin

Melanocytes make dark pigments to shield the skin cells from damaging sunlight

Melanin

This is the pigment that gives the skin its colour. It comes in two forms: brown-black eumelanin and red-yellow pheomelanin.

Melanosome

Melanocytes stuff packets of melanin into membrane-covered bundles before sending them out into the skin.

Keratinocytes

These cells make up the outer layer of our skin, and their DNA is vulnerable to damage from the Sun's rays.

UV light

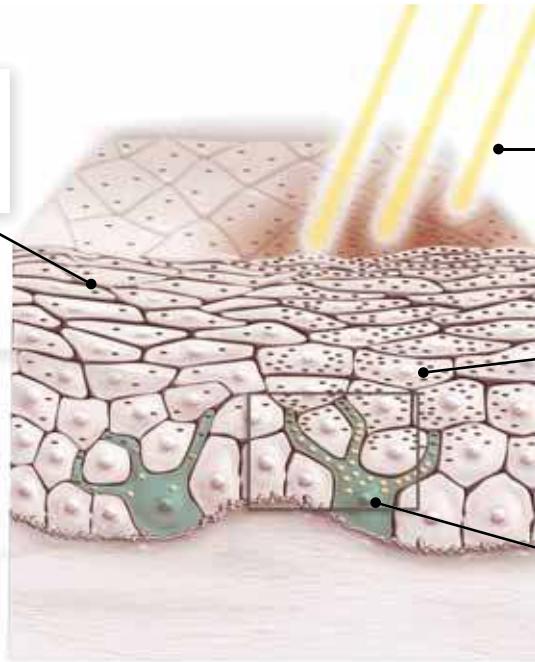
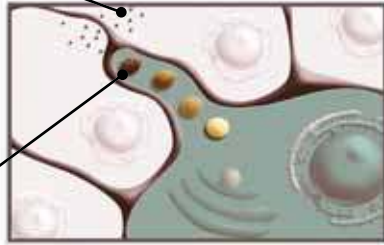
When light hits the skin, cells called melanocytes start to produce extra melanin.

Tanning

Keratinocytes use the packets of melanin to cover their nuclei, shielding their DNA from the Sun.

Melanocyte

Specialist cells under the skin make the dark pigment melanin using a molecule called tyrosine.



WHAT IF WE COULD FILTER OUT ALL ULTRAVIOLET LIGHT?

Blocking UV would do away with skin cancer and premature ageing, but at what cost?

Scientists split UV into three bands of wavelengths based on their behaviour. At the most energetic end – 100 to 290 nanometres – there's UVC light; it has the shortest wavelengths and does the most harm. Luckily, the atmosphere filters it all out before it gets to the ground. Between 290 and 320 nanometres there's UVB light; this is the one that tans and burns the skin and causes cancer. The atmosphere gets rid of around 95 per cent of it, and it can't travel far into our bodies, but the little that gets through is enough to do us harm.

Finally, from 320 to 400 nanometres there's UVA; it passes through the atmosphere and through the skin causing damage to the

structures that support our cells. This leads to premature ageing, cataracts and sunburn. Blocking this light could save us from having to apply sunscreen, but it wouldn't all be positive.

Our bodies use UVA light to make vitamin D, and lots of animals also rely on UV for survival. Butterflies use UV in their wing patterns to attract a mate, flowers use it in their petals to attract bees, and sockeye salmon use it to find food. In the Arctic, UV light allows reindeer to spot wolves, whose fur and urine show up black against the snow. And that's just the tip of the iceberg; research is revealing that dozens of other species can see into the UV spectrum. If we got rid of UV light they'd all be left in the dark.



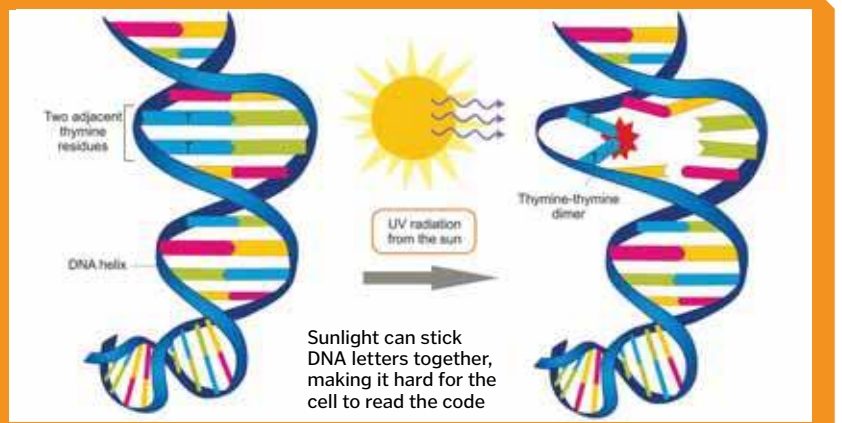
Flowers display intricate patterns to bees, visible only under UV light



Ultraviolet vision can make it easier for animals to spot predators in the snow

What does UV light do to DNA?

When photons of light hit DNA, they heat it up and make it more likely to react with molecules around it. Most of the time the heat is simply released and the DNA goes back to normal, but sometimes two adjacent DNA letters get stuck together. There are four DNA letters – adenine, cytosine, guanine and thymine – and it is cytosine and thymine that are most vulnerable. Their ring-shaped structures can get stuck together, and this makes it hard for the cell's machinery to read the genetic code. When it gets to a pair of stuck rings, it can't work out the sequence, so it has to guess. This can introduce mistakes into the code as the cell copies its genes, and these mistakes can change the way that proteins work. This can then change the way that cells work, leading to skin cancer.





WHAT IF ALL THE VOLCANOES ON EARTH ERUPTED AT ONCE?

The simultaneous eruption of more than 1,500 active volcanoes would be absolutely catastrophic

Of the thousands of volcanoes currently active on our planet, there are a handful that could seriously harm life on Earth if they blew. If they all erupted at once we'd be done for. Cone-shaped stratovolcanoes would spew sticky magma upwards in violent bursts, splattering the ground with molten rock. Dome-shaped shield volcanoes would dribble runny lava out across the floor, engulfing anything in its path. Fissure vents would make curtains of fire and vast lava lakes would open as the ground collapsed. But these would be the least of our problems.

Within moments, ash would bury the Earth. Our machines would stop working, buildings

would collapse, animals would suffocate, and crops would fail. Sulphurous gases would rise high into the atmosphere, blocking out the Sun's light and plunging the whole planet into winter. Then, as the gases mixed with water, they'd rain down on the ground as acid. Oceans would become acidic, the shells of sea creatures would dissolve, and food chains would collapse. In the aftermath, carbon dioxide would create a greenhouse effect, heating Earth so fast that life would struggle to adapt. Only time would tell which organisms, if any, would be able to survive.

Flowing lava consumes everything in its path, from trees and animals to roads and houses



Did volcanoes kill the dinosaurs?

A colossal asteroid struck the Earth just before the dinosaurs died, but it wasn't the only natural disaster to befall our reptilian predecessors. In a part of India called the Deccan Traps, 512,000 cubic kilometres of solidified lava coat the ground, the result of monumental volcanic activity. Eruptions on this scale would have released tons of carbon dioxide into the atmosphere, dramatically changing the climate.

The rock at the Traps dates back to between 60 and 65 million years ago – just before the dinosaurs disappeared. Studies of a lakebed in China have revealed evidence of rising temperatures and accelerating extinctions around the same time. It looks like the dinosaurs were already under pressure from volcanic eruptions; the asteroid might just have been the final nail in the coffin.



The Deccan Traps in India contain solidified lava flows over 2,000 metres thick

Volcanic Earth

Thousands of simultaneous eruptions would turn Earth into a ball of ash, glass and fire

Ashfall

A blanket of ash would rain down on the Earth, burying plants, animals and buildings.

Volcanic winter

Sulphurous gases would block out the light, reflecting sunlight and cooling the Earth.

Earthquakes

Movement of the tectonic plates would send powerful earthquakes rattling around the globe.

Lava flow

Molten rock would burst from the ground, moving at speeds of up to 160kph.

Buried in glass

Molten rock in the air would harden into shards of glass, coating the ground with sharp needles.

Ground collapse

Great plains of lava would open up as land weakens above bubbling pools of molten rock.

WOULD ANYTHING BAD HAPPEN IF WE MADE WASPS EXTINCT?

A delicate balance depends on these picnic pests

Wasps might seem like good-for-nothing pests, but they aren't all bad. In the UK alone there are more than 7,000 different species, although we're most familiar with the 'yellow jackets', *Vespa vulgaris*.

These social wasps live in colonies with a queen and hundreds of female workers. The reason they come out in late summer to attack our outdoor meals has to do with the way they raise their young. Wasp larvae make a sweet juice for adult wasps to eat, but by August the young are all fully grown. So the adults, still craving a sugar fix, head out in search of fizzy drinks, jam and cake.

Getting rid of them isn't the answer; wasps play a critical role in controlling insect numbers. They catch and kill pest like greenfly and caterpillars, keeping ecosystems in balance and protecting our gardens from destruction. If they went extinct our picnics would just be overrun with other insects.



Jam-hungry yellow jackets invade your barbecue in search of a sugar fix

WHAT IF ALL OUR ANTIBIOTICS STOPPED WORKING?

Bacteria are waging war on our drugs, and defeat is not an option

Until the 1940s, one in 20 children died before their first birthday. Tuberculosis and pneumonia had no cure, and a simple cut could turn a limb gangrenous, resulting in amputation. Antibiotics stop bacteria dividing, slow their growth or burst them open, helping our immune cells to clear infections. They eliminate deadly diseases, allow us to open the body up for surgery and protect cancer patients from infection. They make it possible to farm animals and fish on an industrial scale, and their presence in cleaning products stops the spread of disease. But bacteria are fighting back. In 2016, 700,000 people died as a result of antibiotic-resistant infections, and by 2050, 10 million lives a year could be at risk.

Like us, every individual bacterium is slightly different, so when a colony of bacteria encounter antibiotics Darwin's survival of the fittest kicks in. Some individuals do better than others, living longer and passing on their genes. This makes the next generation a little bit better at resisting the effects of drugs. That next generation also accumulates random mutations, making them each a bit different from one another again. Some get even better at resisting antibiotics and the cycle repeats. These small improvements start to add up, and eventually we end up with bacteria that we just can't kill.

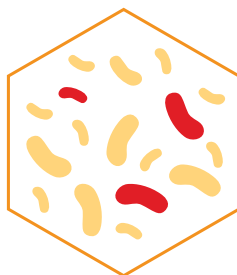
We are in an arms race with these microscopic organisms. They are evolving molecules that ignore antibiotics, inactivate them, or even pump them out of their cells. What's more, thanks to a quirk of bacterial biology, once one species has developed a way to resist a drug, it can donate its genetic code to another species, passing the resistance on. If our drugs stop working, treatable infections could once again become deadly, the risk of infection after surgery could rise, and industrial farming could become impossible. It's a race against time to find new ways to fend them off, a race that we can ill afford to lose.



The more we use antibiotics, the more chances bacteria have to develop resistance

The rise of resistance

As bacteria fights back, the antibiotic war is far from over



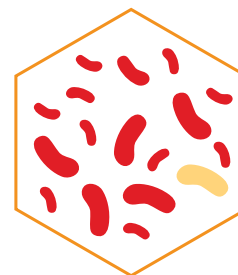
A mixed army

Each bacterium in a colony is slightly different – some are naturally a little harder to kill than others.



The strong remain

Antibiotics kill or inactivate the weakest bacteria first, thereby leaving the stronger bacteria behind.



Share to survive

The offspring of the surviving bacteria inherit the genes that make them harder to kill.



Resistance

Bacteria can share genes, allowing them to pass antibiotic resistance to other species.



The physics of MJ's moves

The real magic behind his iconic routines

Beloved for his musical talent and song-writing ability, Michael Jackson is also remembered for his unique dance moves. From the robot to his high kick, he brought a myriad of moves to the stage. One particular trick from the 1987 video for *Smooth Criminal* made audiences scream: he bent forwards by 45 degrees from his ankles without moving his feet or losing balance. The move defied physics and physiology, but thanks to some fancy footwear Jackson could take the principle of gravity and beat it.

Our centre of gravity is the point at which an object's weight is evenly balanced on all sides. When you stand up straight this point is around your midriff. Imagine a vertical line passing through your body from the top of your head through the centre of gravity and down towards the ground. When this line is no longer straight our centre of gravity brings us closer to the ground, and unless we steady ourselves we fall.

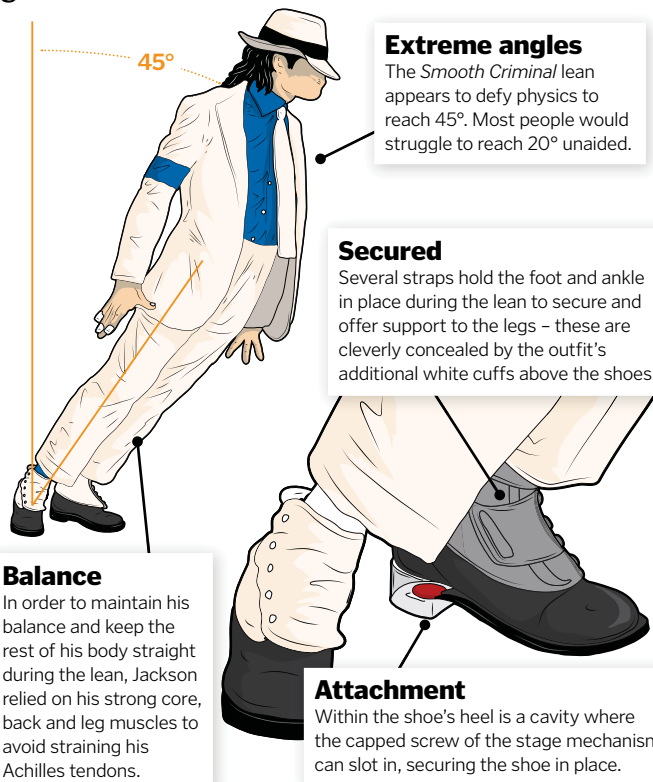
Without moving their feet, the average person can only lean around 20 degrees, so how did Jackson achieve more than double that? It was all thanks to some ingenious shoes. Hidden beneath the heel, his patented system allowed him to hook onto the stage and lean further forward. Capped screws protruding from a section of the stage were slotted into a groove on the heel and straps at the ankle supported the foot. Even so, this move still required great deal of muscle strength.

Creating the anti-gravity effect

MJ's famous gravity-defying move was more of a feat of ingenious engineering



Michael Jackson is responsible for popularising the robot and moonwalk



Moonwalk motion

If you've ever wondered how to do the moonwalk then you are not alone. Here's how...



1 Find a smooth surface

First you need the right surface. Smooth surfaces, such as hardwood floors, are a good option for a fluid moonwalk.



2 Raise right heel

While keeping the ball of your foot on the ground, raise the heel of your right foot behind your left leg.



3 Slide

Support your weight on your right foot so you can move the left. Without moving your right foot, slide your left along the floor without lifting it up.



4 Snap

Once your left foot has passed your right, switch their positions so your right foot is now flat and the left foot is raised with the ball on the floor.



5 Slide

Having transferred your weight to the left foot, you can now move your right. Keep your left foot still and slide your right along the floor.



6 Repeat

Continually slide and snap your foot position and don't stop 'til you get enough movement to create the moonwalk.

Snowflake chemistry

How do these delicate frosty flakes form, and are they truly unique?

Snowflakes form around tiny particles of dust or pollen floating through the atmosphere; as a particle passes through clouds of water molecules, they stick to its surface to form a droplet. At freezing temperatures high in the atmosphere, this droplet begins to freeze and form crystal faces. These crystals begin the formation of the snowflake's shape.

The reason for their symmetrical shape is due to the structure of the water molecules. Hydrogen and oxygen atoms bond together at a 104.5-degree angle, creating a V-shaped structure with two hydrogen atoms attached to one oxygen atom in the middle. As water

molecules bond to one another, six of these 'V' structures form a hexagonal shape. This process continues and the crystals begin to fall as more water molecules join the frozen particle party – as many as 1 billion billion (10^{18}) water molecules can be present in the average flake!

The surrounding temperature of a falling snowflake will increase as it nears the ground. This limits the amount of freeze and the number of water molecules that can join onto it, creating spiking symmetrical structures, although with many variations.

As the old saying goes, no two snowflakes are ever the same. During its descent several

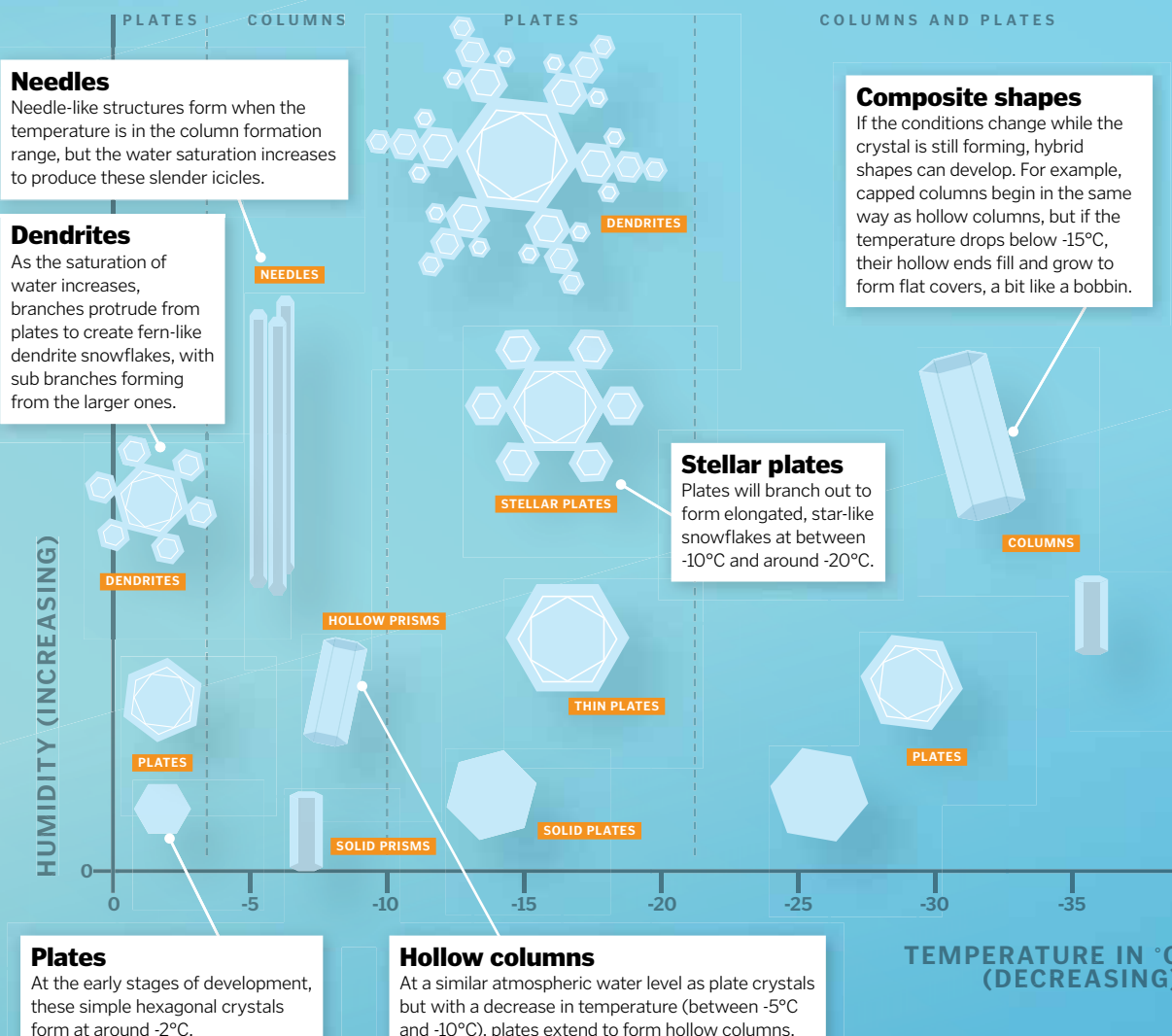
Stellar snowflakes form when water molecules collect at the outermost points of the snowflake, creating branches



factors affect the eventual shape and size of a snowflake. Humidity, wind, temperature and even the variant of hydrogen atoms present – all these factors have an effect on flake formation. Unless each individual water molecule and forming crystals are exposed to the exact same conditions they will not form in the exact same way, which explains the countless varieties of snowflake.

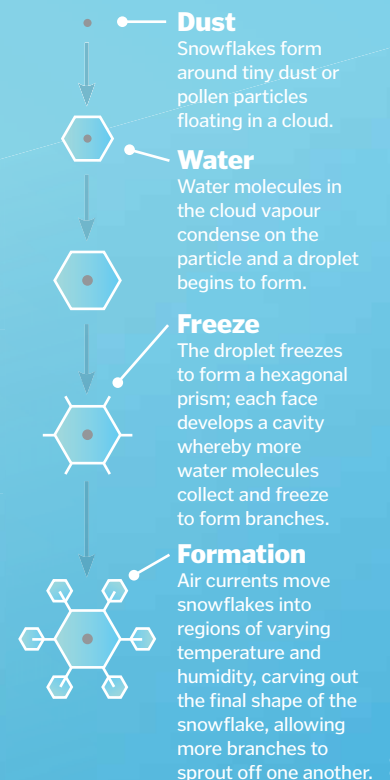
Sculpting a snowflake

How do temperature and humidity affect flake formation?



Growing snowflakes

From dust to dendrites, snowflakes take a chilling journey on their way to the ground



Unlock!

The doors are locked, you don't have much to work with and the clock is ticking. Will you escape?

The premise of *Unlock!* is that you are locked in a room and need to solve a series of clues to get out. After choosing a scenario, you and your friends must work together to complete the objectives, solve all the puzzles and escape before time runs out. The gameplay is very straightforward, which allows you to pick up the rules quickly, and a free app enables more interesting gameplay while assisting the more routine aspects of the game.

Unlock! begins once you have started the timer on the app. Having read the objectives for the scenario on the back of the main card, you flip it

over to reveal the first room. Each player is then dealt a number of cards – face down – which hold clues to assist the escape. The room card displays the layout of the room as well as a collection of numbers; these relate to the numbers on the back of cards in the rest of the deck. Each player can now reveal the cards whose numbers are shown, and these are what the team have to work with to solve the puzzles.

There is a small selection of cards you'll be confronted with during the game: items, machines and codes. These items can be combined to make new items or reveal a solution

by combining objects. These new cards will help you progress, but you must be careful! Proceed with logic and communicate with your team, because combining the wrong items can result in the reveal of a penalty card. The same applies to Code and Machine cards – the wrong answer results in a time penalty.

The game also likes to conceal things, so keep your eyes open for clues hidden within the cards. Similarly, code-breaking assets are also hidden on other cards, so check all the cards carefully and think outside of the box so that you find everything you need. Good luck!



- Publisher: **Space Cowboys**
- Price: **£26.99 (approx. \$35)**
- Number of players: **2-6 (but can be single-player)**
- Typical game time: **30-70mins**

Work with what you have

There is always a solution – you may just need to change your perspective on the problem

Machines cards

Machine cards work with the app, enabling you to engage with the machine displayed in the artwork. However, the method of operation is often hidden elsewhere in the game.

Penalty cards

Reveal one of these and you and your friends will lose valuable time.

App

The app keeps track of the remaining time, penalties and hints and provides a more interactive aspect to certain challenges.

Code cards

These are a variety of locks that take a four-digit code to unlock. These codes are scrambled and hidden in puzzles involving words, colours and images on other cards.

Room card

Often a game will contain more than a single room card, which opens up a lot more opportunity in the game.

Objects cards

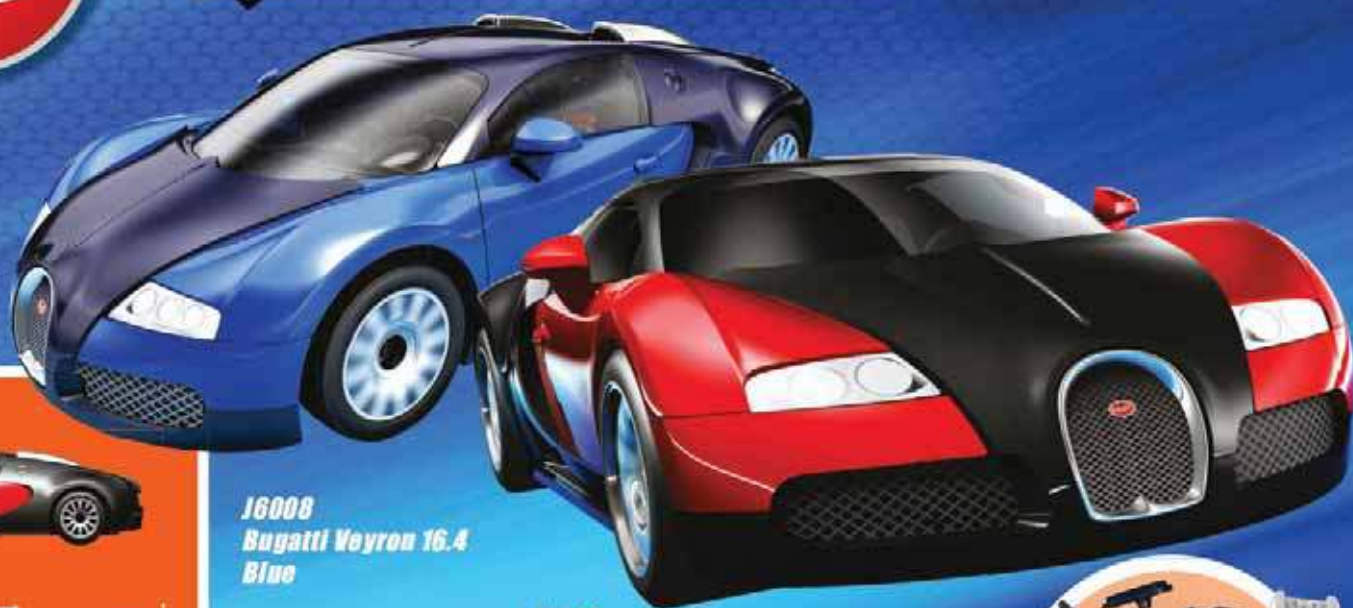
Objects cards can only be combined with cards of the opposite colour (red or blue). They are the main cards of the game and can be used in unusual ways, so think creatively.

Deck





QUICKBUILD



J6008
Bugatti Veyron 16.4
Blue

J6020
Bugatti Veyron 16.4
Red



A Model Supercar The Brilliant Bugatti Veyron

Would you add the Bugatti Veyron to a line up with the VW Beetle and Camper Van? Ordinarily, possibly not. So what connects these cars, each iconic in their own right? Some car enthusiasts out there may already know but they were all in fact designed and developed in Germany by world renowned Volkswagen.

Creating a street-legal super car was never going to be easy. The vast majority of the components for the Veyron had to be designed, developed and manufactured entirely from scratch. Gordon Murray, designer of the McLaren F1, once referred to the development of the Veyron as "The most pointless exercise on the planet." However, following a test drive for Road and Track magazine Murray referred to the car as "a huge achievement" being particularly impressed with the engine and its transmission capabilities. In the decade long production period only 450 Bugatti Veyrons were ever produced. An incredibly small number considering the car's world renowned fame.

On the 15th April 2003 Bugatti was awarded "Fastest production vehicle of all time" for the Super Sport version of the Veyron by Guinness World Records,

having achieved a speed of 267.856 mph, interestingly customer cars were electronically limited to 258mph which did raise the debate as to whether it was fair that Bugatti were awarded the record, but Guinness World Records debated this and confirmed it was valid.

The car won multiple awards including "Car of the Decade" in Top Gear's 2010 award show. All three presenters showed a huge amount of respect for the record-breaking super car with Jeremy Clarkson even stating that it was "the greatest car ever made and the greatest car we will ever see in our lifetime."

The Bugatti Veyron has earned worldwide acclaim for innovation, speed and beauty. You can create your very own at home with an Airfix QuickBuild Kit. QuickBuild kits give you the ability to recreate a wide variety of iconic aircraft, tanks and cars into brilliant scale models. No paint or glue is required, the push together brick system results in a realistic, scale model that is compatible with other plastic brick brands.



2	m 4.462	m 1.204
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WILDLIFE WARRIORS

Meet the people fighting wildlife crime and helping animals in need through rescue, rehabilitation and research

Words by **Charlie Evans**

Lonesome George was thought to be over 100 years old. The giant tortoise subspecies (*Chelonoidis nigra abingdoni*) was known as an 'endling' – the last known individual of a species. He lived his life on the small island of Pinta, one of the Galápagos Islands off the coast of Ecuador, but his species was hunted to the point of extinction.

After scientists first discovered him, they had hoped they would find another. Instead, they soon learned that the vegetation that George once feasted upon was now being destroyed by hoards of feral goats that had been released there by humans who wanted something to hunt. But there was no sign of another tortoise like George. With no offspring, when he died in 2012 the species became extinct.

Lonesome George's story is heartbreaking, but it is not unique. The last decade has seen the extinction of so many creatures: the Japanese river otter, Malagasy hippopotamus, eastern cougar, Christmas Island pipistrelle. Other species are hurtling towards a similar fate, teetering on the brink of extinction, like the Ili pika, Darwin's fox and the Bornean orangutan.

From climate change, toxic pollutants and natural disasters to mass deforestation, illegal trapping, and poaching, these species are suffering at the hands of humans. While desperate attempts are being made to keep these animals in captivity with the hopes of reintroducing populations into the wild, it is seemingly too little too late. The real answers to

saving the planet's wildlife is preventing a species from declining to such dangerously low numbers through education and research, focusing on fighting wildlife crime like illegal poaching for the trade of exotic pets and heading out into the bush to save animals battling disease and life-threatening wounds.

One organisation that works tirelessly to preserve animals is the Lilongwe Wildlife Trust based in Malawi, a country home to about 192 mammal species, including the critically endangered south-central black rhino and the endangered African wild dog. Malawi is also southern Africa's main transit hub for illicit wildlife products like elephant ivory, animals for sale in the illegal pet trade and bushmeat.

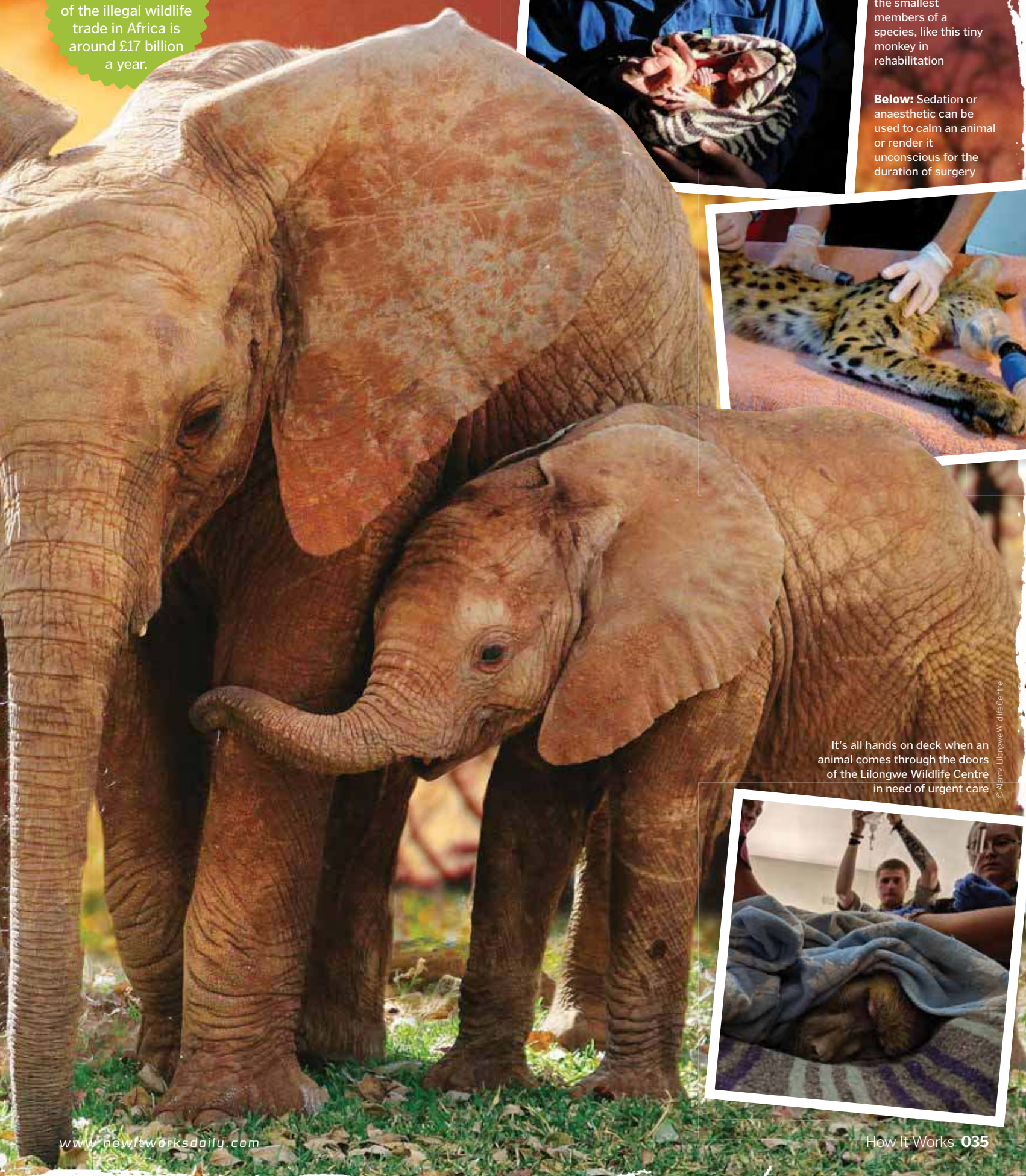
Their centre opened its doors in 2008 as Malawi's only animal rescue and rehabilitation facility, and it is the only sanctuary in the world to have received all three accreditations from the Born Free PAW scheme, GFAS (Global Federation of Animal Sanctuaries) and PASA (Pan African Sanctuary Alliance). Since then, Lilongwe Wildlife Trust has developed into a world-renowned and award-winning conservation organisation.

We meet some of the heroes behind these conservation efforts, who are working to protect and preserve the wildlife of Malawi and striving towards the goal of saving every wild animal in the country from suffering.

"The last decade has seen the extinction of many creatures. Others are teetering on the brink"

DID YOU KNOW?

The estimated value of the illegal wildlife trade in Africa is around £17 billion a year.



Left: Wildlife conservation often requires caring for the smallest members of a species, like this tiny monkey in rehabilitation



Below: Sedation or anaesthetic can be used to calm an animal or render it unconscious for the duration of surgery

It's all hands on deck when an animal comes through the doors of the Lilongwe Wildlife Centre in need of urgent care

© Alamy, Lilongwe Wildlife Centre



Animal rescue: the frontline

The paramedics of the bush, wildlife vets track and treat animals in their natural habitat

Making quick decisions, juggling a team and administering medication, all while the life of an animal is in their hands – being a vet is a challenge. But out in the wild things get even harder. Bush vets battle intense heat and trek long distances to reach the injured creatures that desperately need their help. The country-wide Wildlife Emergency Response Unit (WERU) is run by Lilongwe Wildlife Centre and focuses on helping some of Malawi's larger creatures. The unit has saved the lives of almost 100 injured animals over the last three years, the majority being elephants or rhinos that have been caught in poachers' snares.

TECHNOLOGY AND TRADITIONAL TRACKING

Rescuing an injured animal takes patience, endurance and knowledge, but before an animal can be patched up by a team of wildlife vets, it first needs to be located. Traditionally, tracking has been done manually with experienced trackers, who will follow clues through the bush until they find the injured animal. They look for any tiny disturbance that suggests their target may have been in the area, such as footprints or sticks that have been snapped or have evidence of saliva. The expert scouts at Lilongwe Wildlife

Centre can even identify which individual they are tracking by measuring the footprints they leave behind in the ground. But this traditional method has some drawbacks.

Though the trackers can usually age a set of tracks, they can't often determine exactly how far away the animal is from where they are standing. This is the advantage of using modern telemetry, which places a transmitter on an animal that can then be monitored by the animal rescuers. Some animals, such as birds,

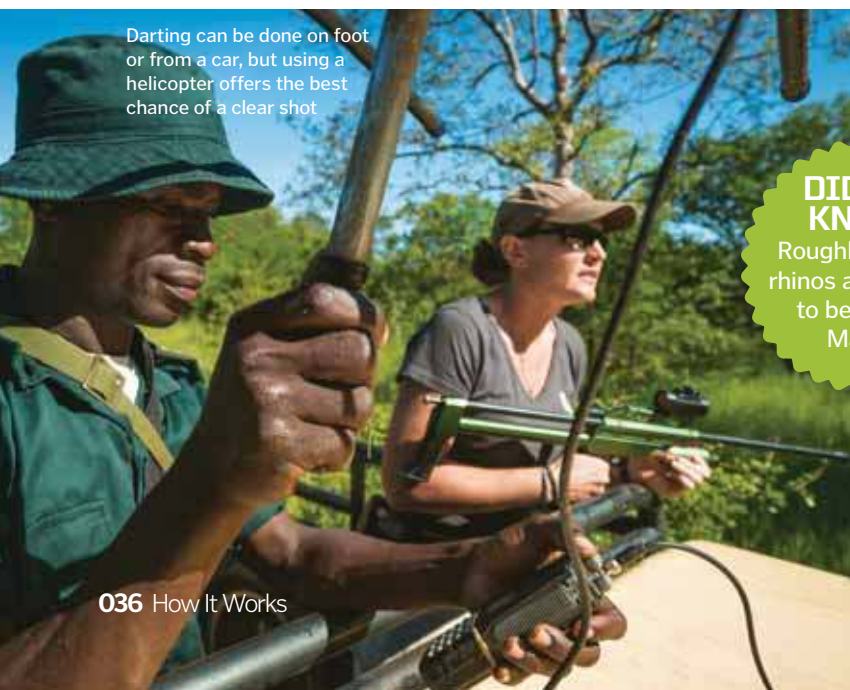
can wear a transmitter like a backpack, while others have them glued onto their shells or drilled into their horns (a painless process).

The transmitters emit a VHF signal that can be detected by the scouts on a receiver to give them an accurate position. This precision means it is easier for rescuers to stay downwind from the animal, so they are unable to smell the approaching humans, thereby making it easier to dart the animal in question and bring it in for treatment without it getting spooked.



Dr Amanda Salb commonly sees life-threatening snare injuries, which she treats in the bush by removing the wire and cleaning the wound with antiseptic

"I love working with the park rangers, who are out there every day protecting these animals"



Darting can be done on foot or from a car, but using a helicopter offers the best chance of a clear shot

DID YOU KNOW?
Roughly 14 black rhinos are thought to be living in Malawi.



Animal rescue also deals with retrieving creatures that have been illegally captured, like this pangolin, who was going to be killed so its scales could be sold

WILDLIFE CAPTURE

Once an injured animal has been located, it must be captured for the wildlife vet to start work on administering treatment. This is done using anaesthesia or chemical immobilisation. Sometimes this is applied by first leaving bait containing a sedative such as diazepam to make it easier for the vet to dart the animal with anaesthetic. These darts are usually a combination of anaesthetic plus a sedative or tranquillisers. The sedative reduces the amount of anaesthetic needed for the animal to be immobilised. Large animals like elephants can handle small amounts of much higher-potency narcotics like etorphine.

Other methods of restraint include net-gunning, live traps and plastic boma, which are often preferred, as darting can be difficult and must penetrate a large muscle to prevent injuring the animal and ensuring the dose is administered effectively. Once an animal is down the vets can get to work, removing snares, administering medication or even performing minor surgery out in the bush.

Treating animals 'in situ' means that larger animals can receive emergency care much quicker

5 THREATS TO WILDLIFE

1 Snares

Snares are metal loops that are attached to trees by hunters to trap animals. Some animals manage to escape, but they can be left with wire cutting into their neck or leg, wounds that can become infected.

2 Poaching injuries

Injuries sustained from illegal hunters include gunshot wounds and gaping injuries caused by an animal having its tusks, horn or scales removed.

3 Entrapment

Trapped animals in areas where humans are living, such as gardens or resorts, need to be relocated, often for both the safety of the animal and the people residing in the area.

4 Illegal pet trade

Wild animals kept as pets often suffer malnutrition and the effects of stress as they've been kept in poor conditions.

5 Disease

Wild animals are susceptible to disease such as cancer, respiratory infections, ulcers and septicaemia.

DID YOU KNOW?

The bald eagle was nearly wiped out by the pesticide DDT, but since that was banned the population has increased.



Q&A

Q&A with animal rescuer Dr Amanda Salb

Shooting darts from helicopters, capturing hyenas and tracking lions – it's all in a day's work



Dr Amanda Salb is the head veterinarian for the Lilongwe Wildlife Trust and runs the Wildlife Emergency Response Unit. Her job requires her to ensure that injured animals receive treatment fast, and no animal is too big.

Your job sounds exciting; you're really the frontline response for making sure animals in danger get help. What is your favourite part of what you do?

The best part of my job [is that] we are all a team working together to help these animals. I love working with the park rangers, who are out there every day protecting these animals and finding injured animals. My colleague James Kamtsokota is one of the best trackers I've worked with, both at following tracks and using telemetry.

Do you have an animal rescue highlight when you look over the last few years?

We got a call about a hyena that had gotten caught inside a resort. I drove there and darted him, and the helicopter met me there and we shoved the hyena in the back of the helicopter and flew back to Liwonde National Park to release him. He was seen a couple of months later hanging out with the resident park hyenas, so it was such a happy ending!

Jumping into helicopters, capturing big wild animals – it all sounds really adventurous. What qualities do you need to be a wildlife vet?

Endurance, patience, creativity and the desire to be a team player. It seems very glamorous and fun, but when you are hot, scratched and bug-eaten, it can be marginally less fun and decidedly less glamorous. An ability to think on your feet helps.

What are the biggest threats to wildlife?

The illegal wildlife trade, for body parts like horn and ivory, is definitely a big threat. We can work very hard on the ground to try to prevent poaching, but as long as there is a demand and money being paid for these items there will always be a loss of life.

Is there any technology or equipment that you rely on every day for animal rescue?

I use a dart gun, binoculars and a rangefinder as primary tools. I have gotten to do work out of a helicopter, which is a really valuable piece of equipment and technology.



Baby monkeys in rehabilitation are swaddled to mimic the feeling of being carried in their mother's arms

"Lilongwe Wildlife Trust has rescued and rehabilitated over 800 animals, more than half of which have been released back into the wild"

Animal rehabilitation: rest and recovery

Getting animals back on their feet (or paws) is no easy task

When an animal can't be rescued on the scene by bush vets, or they are being rescued from an environment where they have likely suffered from poor treatment, bringing them into a veterinary clinic is their best chance of survival. Here, teams have access to a vast array of life-saving medicine and technology to help the animals to recover and return to the wild.

These animals are often babies who have become separated from their group or who have been orphaned by poaching that require expert hand rearing. Others have ailments like broken bones or tumours that need monitoring and continued treatment. When safe at a rehabilitation centre, they are examined, medicated and given a nutritious diet while they rest and recover. They are then re-socialised with members of their species.

A NEW LIFE

It is the ultimate aim of every conservation worker to return the animals in their care back

to the wild where they belong, but some creatures will not be able to function in their natural habitat again. These animals, usually the ones who have been seriously injured or were orphaned at a very young age, are given sanctuary – a forever home within a professional facility that can ensure proper care and space for them to live happily.

When the time comes to release these animals into their new home, a 'soft release' method is used to enable them to adjust to their new environment at a slow pace and keep stress to a minimum. The animal is first anaesthetised at the rehabilitation clinic so it can be moved into a travel crate. The crate is then placed in the new enclosure within the release site, with lots of food and water, and the animal is free to leave the travel crate in their own time. At Lilongwe Wildlife Trust, in total over 800 animals have been rehabilitated, with over half released back into the wild. At the moment there are 199 animals at the centre under rehabilitation.

DID YOU KNOW?

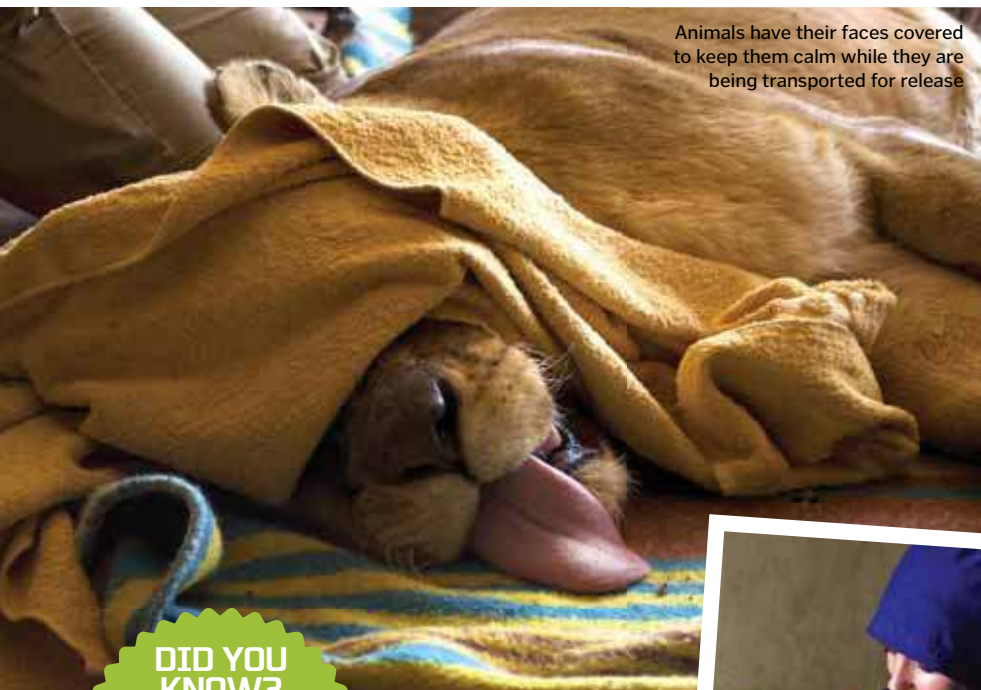
The Asiatic lion had been hunted to just 20 individuals, but a breeding programme has since boosted the population to 523.



Since the early 20th century African elephant numbers have dropped from 3-5 million to just 415,000 today



Check-ups and monitoring of the animal's health are usually done under sedation for the safety of both the animal and its carers



Animals have their faces covered to keep them calm while they are being transported for release

DID YOU KNOW?

It's estimated up to 7,000 tigers are currently living in captivity in the United States.

Caring for baby animals involves preparing nutritious food and adhering to feeding schedules



Transport crates are used in 'soft releases' so the animal has time to adapt to the change in environment

Q&A

An interview with animal rehabilitator Dr Alice Dumoulin

Medicating, monitoring, hand rearing and releasing is all part of daily life at the rehabilitation centre



Dr Alice Dumoulin is a veterinarian at the Lilongwe Wildlife Centre who specialises in the care of wild animals, especially birds. Her job is to patch up the rescued animals, keep them safe and get them healthy enough to be released.

What is the process of rehabilitating an animal?

Rehabilitation is a very long process. Animals often arrive dehydrated, skinny, sometimes with injuries. The first job is to stabilise them medically and build up their strength. I work closely with the rehabilitation manager Alma van Dorenmalen, as well as Soft Mbanda, [who is an] animal carer. Soft is with the animals every day and he is my eyes and ears, looking out for any injuries. If a procedure needs to be done, he will catch the animal and help me monitor it during anaesthesia. Alma will find the best settings to let the animal express its natural behaviour and stay as wild as possible.

What does a day in your life at work look like?

A typical day includes management of medication, health checks, quarantine exams and checking the evolution of wounds. I also teach practical skills such as suturing and darting to international and Malawian vet students.

What sort of situations require rehabilitation?

Wild animals kept as pets, young animals that have been orphaned after a road accident or poaching, wildlife that has been trafficked for bushmeat, and animals coming into conflict with humans because of deforestation, are just a few examples.

Are there any particular animal rehabilitation cases that stand out as particularly successful?

It was very rewarding to have been part of the rehabilitation of Indigo, a baby blue monkey who was kept as a pet and had never seen grass or trees or other blue monkeys in her short life. When she arrived at the centre she needed a lot of care to stabilise her. At first she was so scared to go out of her room, so it was wonderful to eventually see her be accepted and cared for by all the other blue monkeys in the troop.



Wildlife research: fighting for the future

Population health, interaction with humans, disease status – tomorrow's challenges require answers today

While rescue and rehabilitation projects focus on the present situation, research looks towards the future. Conservation research attempts to understand populations of vulnerable species, determine what risks they may be facing in the wild and advise on how best to protect them. At Lilongwe Wildlife Centre there are multiple projects centred around elephant and primate conservation, in addition to the Clinical Projects in One Health, which seeks to provide clinical intervention and passive disease surveillance in Malawi.

ZEBRA IDENTIFICATION TO MONITOR HERDS

A leopard can't change its spots, and nor can a zebra change its stripes. Just how humans have unique fingerprints, every zebra in the world has a unique stripe pattern, which can be used to identify them. Conservation researchers use stripe-recognition methods to monitor individuals and track them throughout their lives while they are studying the animals.

Lilongwe Wildlife Centre uses a photo registry to keep track of all of the zebras that have been surveyed over the years. Malawian and international veterinary students assist with this zebra surveying by taking three clear photographs of the animal (one of the left side of the body, one of the right side of the body, and one from the rear). The students and researchers compare their photos to the registry and record any notes as they check to see if they seem healthy and free from disease or if there is something to be concerned about. If two photos

of the same zebra are being compared, the stripe pattern will match around the eyes, neck, shoulder, upper front legs, side body, upper back legs and base of the tail. If they have photographed a zebra not featured in the

registry, they have discovered a new individual and are allowed to name it.

CAMERA TRAPS FOR POPULATION CALCULATIONS

Researchers can use camera traps to calculate population numbers, such as animal

abundance and density, which can inform wildlife management decisions. If a species starts to increase by too many individuals, it might be appropriate to move some of them into another protected area that is lacking the species. If a sudden decrease in population is observed, researchers can start raising questions about why this is happening. Could it be a disease affecting reproduction, or a new poaching group that has started to target them?



Images from camera traps provide an insight into the behaviours of some species, like these yellow baboons



Human-wildlife interactions, like this primate hanging out at a local pool, are important for conservation researchers to determine how diseases could be spreading from humans to animals (or vice versa)

"Wild animals are not very cooperative and the plan is always subject to change"

Get involved at Lilongwe Wildlife Trust

To get involved at Lilongwe Wildlife Trust you can either visit as a sanctuary volunteer, undertake a vet externship (for qualified vet/vet nurses who want to gain experience in a different environment) or complete a research placement (for MSc, MRes or PhD students).

Volunteers may be involved in animal husbandry, orphan care, vet clinic support, maintenance, observations and integrations, as well as education and community outreach. There is also the opportunity to spend part of the placement undertaking elephant research at LWT's bush research camp.

For more information on volunteering at Lilongwe Wildlife Trust, email lilongwewildlife@gmail.com or visit www.lilongwewildlife.org.



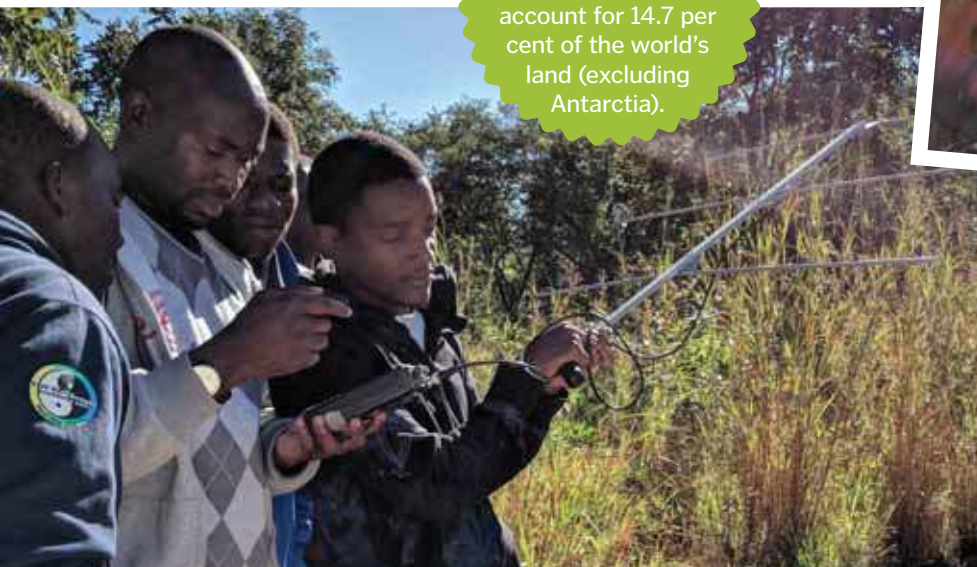
Volunteering in animal conservation could be your first step towards a career in preserving wildlife



Microscopes are used in wildlife research to monitor and collect data about parasites living on animals

DID YOU KNOW?

Designated protected areas for wildlife account for 14.7 per cent of the world's land (excluding Antarctica).



Tracking animals using telemetry is vital when researching moving populations such as zebra

Q&A

Dr Hezy Anholt and community outreach officer Patricia Lato



Testing faeces for parasites, setting up camera traps and vaccinating animals – work at Clinical Projects in One Health is far from average

Dr Hezy Anholt and Patricia Lato work for Lilongwe Wildlife Trusts' Clinical Projects in One Health. Dr Anholt's research seeks to better understand disease and collect data on human-wildlife conflict, and Patricia Lato manages vaccination clinics and organises community meetings to discuss animal health concerns.



How did you get involved at Lilongwe Wildlife Trust?

Patricia: Kuti Wildlife Reserve management employed me as a community worker. My job was to sensitise the communities about environmental problems and conservation of wildlife and natural resources. In 2016, Catherine Wood from Rift Valley Wildlife Clinic asked me to join her to assist [in] rabies vaccination. In 2017, Hezy Anholt joined Catherine and asked me to be involved in the One Health Project.

Could you talk a bit about your work? Could you share some of your findings with us?

Hezy: We found *Toxocara* in wildebeest – that's never been reported before. What health effect it might have on wildebeest is unknown, so we are investigating what the implications could be and whether domestic cattle play a role in transmission.

Patricia: Through a survey I discovered that no one is keeping wild animals [as pets] in the villages surrounding Kuti Wildlife Reserve. Also, I discovered community members are moving long distances to find veterinary care.

What challenges do you face in your work?

Hezy: Wild animals are not very cooperative and the plan is always subject to change. You might follow a baboon troop for five hours without getting a faecal sample, or find that every zebra in the park appears to be hiding on the day of your zebra survey.

Patricia: The biggest challenge I face is the irritation of some community members [due to misinformation]. Human and wildlife conflict is also a big challenge.

Hezy: Misinformation has caused some community members to distrust our programme. We noticed a big increase in programme participation in certain villages after Patricia was able to visit the communities, hold meetings and address people's concerns adequately.

Identify the zebra

Take a close look at the stripes to see if you can match each zebra with its close-up



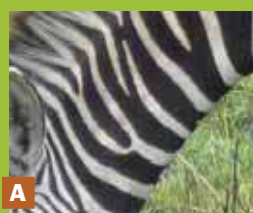
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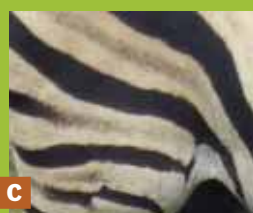
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The Rainbow Mountain

Discover the origins of the colours cascading over Peru's iridescent Ausangate Mountain

Stretching over 7,200 kilometres along the western spine of South America, the Andes is the world's longest mountain range. It spans seven countries, but it is in Peru where one mountain in particular stands out from its surroundings.

Around 100 kilometres from the Peruvian city of Cusco is Vinicunca Mountain, which looks as though it's from the world of Dr Seuss rather than our own. Stripes of alternating yellows, reds and greens coat every undulation and edge of its rocky protrusions, giving the 'Rainbow Mountain' its nickname.

This multicoloured appearance is the result of millions of years of sediment layering. Over time, layers of different sediments with different mineral and chemical compositions (dependent on the environment at the time) covered one another. While exposed to Earth's

atmosphere, each layer's composition reacts with the elements in the air, such as oxygen. It's these interactions that produce the array of colours to form the mountain's rainbow appearance. Iron-rich sediment creates the red iron oxide layers, iron sulphide is responsible for the yellow layers and chlorites produce the green.

The Andes formed around 6 to 10 million years ago when the oceanic Nazca Plate subducted (slid underneath) the continental South American Plate, causing uplift. It is thought that this tectonic interaction also generated a lot of volcanic activity, which could explain the presence of the mountain's multicoloured minerals. Through millennia of further tectonic activity these sediment layers have been tilted on their side, so the stripes appear to run vertically.

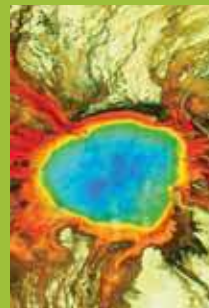
Thousands of years of weathering has helped create the mountain's rusty shades



Earth's vibrant formations



Alum Bay, UK
These clifftops are comprised of quartz, feldspar and mica, but due to contamination from other minerals the cliffs display a mottled array of reds, greens, yellows and browns.



The Grand Prismatic Spring, Wyoming, US
Found in Yellowstone Park, this spring hosts several species of bacteria, which contribute to its rainbow graduation.



Zhangye Danxia, China
Known as the 'The Rainbow Mountains of China', these colourful creations of the Himalayas formed by a similar method to their Peruvian counterparts.



Antelope Canyon, Arizona, US
One of the most photographed places on Earth, this canyon's flowing sandstone appears to change colour depending on sunlight, depth and the weather.



Fly Geyser, Nevada, US
This semi-artificial formation was a failed attempt at drilling a well; the geyser created its colourful cone structure as algae and minerals in the water collected on the surface.

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Reindeer and the people of the Arctic have braved the cold together for around 3,000 years

How reindeer survive the cold

Most people would find a day in the Arctic difficult, but reindeer thrive there year round

Life around the North Pole is harsh and unforgiving. On the Arctic tundra, temperatures can regularly plummet below minus 50 degrees Celsius and food is scarce. Having lived in this challenging environment for thousands of years, reindeer – also known as caribou – have evolved a whole host of adaptations to help them survive in the cold.

Large hooves spread out when caribou walk, dispersing their weight and making walking across deep snow much easier. Their large surface area also comes in handy when the animals encounter water on their long migrations. When reindeer aren't on the move, their hooves make useful tools for digging through ice and snow in search of vegetation to eat.

Unlike other deer species, both male and female caribou can grow antlers. These impressive bony structures are also used to dig for food, but their primary use is in combat.

Males clash over access to females and shed their antlers in autumn or early winter when the breeding season comes to an end. In subspecies where both sexes grow antlers, however, females keep theirs until spring to help them defend precious patches of food while they're nursing young calves.

"Reindeer are on their feet an hour after birth"

Reindeer are on their feet an hour after birth and begin to eat solid food as well as their mother's milk at just a week old. These hardy babies are weaned and independent after six months and reach full maturity around the age of four.

Although they may not be constantly at their mother's side any more, young reindeer are rarely alone; caribou are extremely social animals and form herds that number in the hundreds during winter and the hundreds of thousands in spring. Many of these herds remain wild, but some are herded and used by the people that call the Arctic home.

The great reindeer migration

When winter blows in, many reindeer have to travel south to find enough to eat as their breeding grounds become icy, windy and desolate. Herders gather up their animals and begin the long journey to the winter feeding grounds, while wild caribou follow the instinctive pull towards their winter ranges.

Walking, swimming and scrambling, reindeer traverse great distances in search of enough moss and lichen to see them through the coldest months. When spring arrives, the reindeer embark on another epic journey back to the calving grounds, where there are nutritious young plants and fewer predators.

Currently holding the world record for the longest terrestrial migration, the Grant's caribou's round trip through Alaska can reach 4,800 kilometres. While some follow the same well-trodden route each year, other caribou herds vary the direction and distance of their migration to avoid using up all the available food in one place.



Reindeer travel in huge numbers to find enough food to survive winter

The Christmas story

Father Christmas hasn't always used flying reindeer to help him deliver gifts. St Nicholas, the 3rd- and 4th-century bishop on whom the much-loved figure is based, was often depicted riding to homes on a noble white horse or a donkey. The image of the sleigh pulled by reindeer first appeared in an illustrated poem published in 1821. The 1823 poem *A Visit from St Nicholas* (known better as *The Night Before Christmas*) gave names to eight members of the team – Dasher, Dancer, Prancer, Vixen, Comet, Cupid, Donner and Blitzen. Rudolph and his red nose didn't take up his position at the front of the fleet until 1939, when he was invented as part of a department store chain's festive marketing campaign.

Reindeer have been in Father Christmas' employ for a relatively short time



Built for survival

Reindeer have evolved bodies and behaviours that keep them alive below zero

Size matters

Male and female reindeer can grow antlers, but males' tend to be larger and are shed earlier to save energy.

Sticking together

Caribou calves stay close to their mothers for six months, running alongside them on the migration.

Eye adaptations

Reindeer have UV vision, which makes lichen and signs of predators like urine and hair stand out against the snow.

Winter coat

Two layers of hollow hair make up a thick winter coat that traps air and keeps the body warm.

Fighting fit

Males gain weight through spring and early summer so they're at their most intimidating when the rut begins.

Last resort

Males will display and grunt to try and ward off rivals, but they'll fight fiercely if threats aren't enough.

Recycling heat

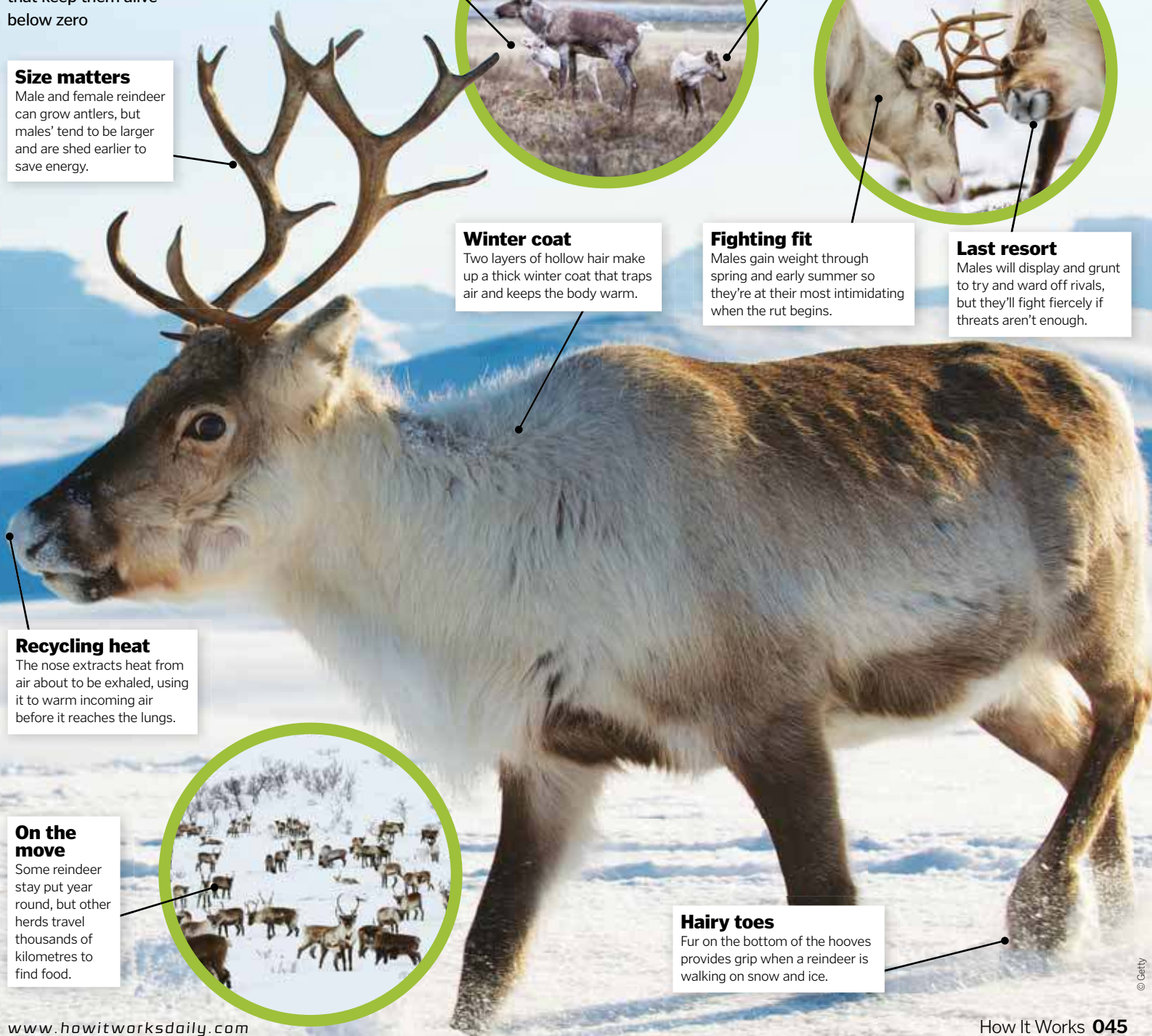
The nose extracts heat from air about to be exhaled, using it to warm incoming air before it reaches the lungs.

On the move

Some reindeer stay put year round, but other herds travel thousands of kilometres to find food.

Hairy toes

Fur on the bottom of the hooves provides grip when a reindeer is walking on snow and ice.



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INSIDE THE CHOCOLATE FACTORY

Discover the wonderful world of chocolate innovation and how beans become bars

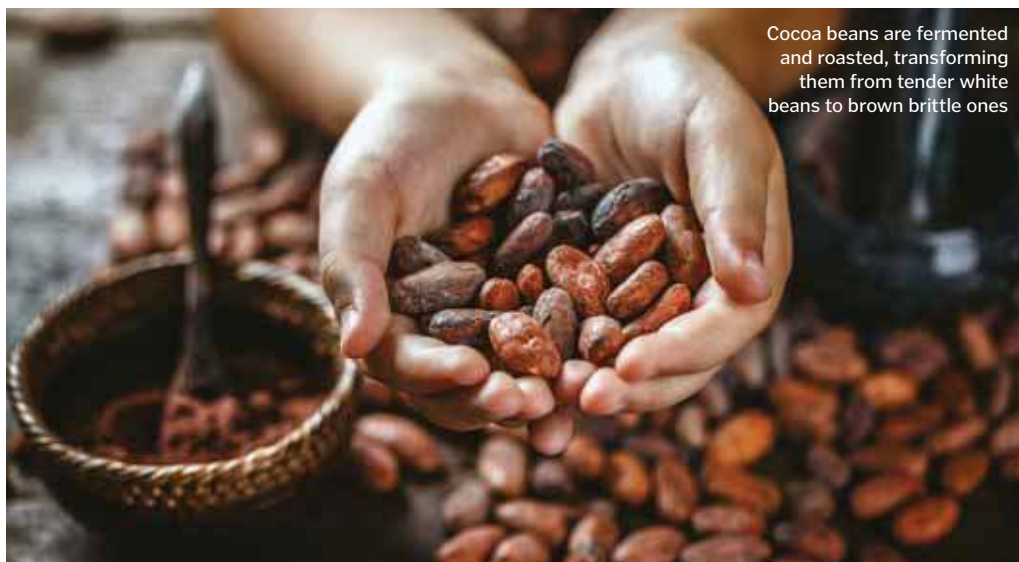
Words by **Scott Dutfield**



As the lead up to Christmas continues to gather pace, so do the sales figures for our favourite sweet treat. Of course, chocolate isn't solely a festive indulgence; many holidays, events or simply a long Monday demand the consumption of some

chocolaty goodness. This delicious indulgence, however, takes a great deal of effort to produce. Built on the back of tiny beans, the chocolate industry is reliant on arguably one of the most diverse ingredients on Earth. Since its discovery thousands of

years ago, our use of chocolate has evolved alongside our manufacturing techniques. Once turned into a bitter drinkable liquid, now our modern-day manufacturing can challenge chocolate's form and function and even its genetic make-up.



Cocoa beans are fermented and roasted, transforming them from tender white beans to brown brittle ones

The mother of chocolate

Meet the Theobroma plant and the fruit that's given birth to a 100-billion-dollar industry

There are 22 species of plant in the Theobroma genus, and the fruit of a cacao tree (*Theobroma cacao*) is the one from which we make chocolate. Cacao is native to Central and South America, and it has been introduced as a crop plant to many African and Asian countries. The ripe fruit consists of a hard yellow shell up to 25 centimetres long, with lines or grooves running along its length. Within the tough exterior are concealed 30 to 40 seeds – cocoa beans – each of which is surrounded by a bittersweet pulp. It is these beans that are mass processed into chocolate. In 2016/17 the three largest producers of cocoa beans – Côte d'Ivoire, Ghana and Indonesia – collectively produced approximately 3.28 million tons of cocoa beans.



Cacao pods grow on trees up to eight metres tall



Cocoa plantations are found mainly in countries located near the equator due to their tropical climates

■ Major cocoa-growing countries

One plant, many products

Cocoa butter

This fat, sometimes known as 'oil of Theobroma', is extracted from the cocoa bean. During the processing of cocoa beans these fats ooze from the beans and form the solid butter, which is used both in the culinary world and the skin care industry.



Cacao powder

There are two forms of powder that can be produced while processing cocoa beans: cacao and cocoa. The former is the purest form of powder, and it's made by cold-pressing the raw beans.



Cocoa powder

Unlike cacao powder, cocoa powder is more processed. It's heated to higher temperatures and is what remains when all of the fat (the cocoa butter) has been removed.



Cocoa mass

This is the solid produced from grinding the roasted cocoa beans without adding sugar to form a solid mass. Cocoa mass can be used as an ingredient in different confectioneries.



Chocolate

Adding milk, cocoa butter and sugar to cocoa liquor will create the final chocolate product.





Mass production

The cocoa bean's journey to the sweet shop

There are many stages between the growing of the Theobroma tree to the packaging of the final chocolate treat. The journey starts at the plantation, where cocoa pods are harvested twice a year. Pods are sliced open with sharp knives and the pulp containing the beans is extracted. Once this pulpy mass has been

heaped into vats (often covered in banana leaves to preserve heat) the next fermentation stage begins. This involves adding yeast to the bean mounts, which will convert the sugar in the pulp that surrounds the bean into ethanol. Heated to around 40 degrees Celsius, the beans are left for roughly five days to completely ferment and turn

a brownish colour. Once dried, these beans can then be shipped for mass production. Different manufacturers start the production of chocolate at different stages. Some complete the process from bean to chocolate bar, while others such as Cadbury import cocoa mass rather than roasting the beans themselves.

Making a chocolate bar

How bitter cocoa beans are transformed into our favourite sweet treats

1 Beans

Beans are imported from cocoa growing countries, where they will usually have been fermented with vinegar and yeast for several days.

2 Loading

Sacks of beans as loaded onto a conveyer belt then sieved and inspected before heading into an oven.

3 Roasting

The beans are heated to 135°C for several hours, with hot air used to dry them out.

6 Cocoa butter

The cocoa liquor is pressed to remove the excess fat. This will later be processed separately as cocoa butter.

9 Conching

The smoothed cocoa liquor goes through conching, a process that removes the bitterness in chocolate. This process reduces the size of the cocoa particles and sugar crystals to around 15 microns (0.015mm).

10 Tempering

In order to create chocolate's smooth appearance and brittle break, liquid chocolate is tempered. This is a process of heating the chocolate to 40°C then allowing it to cool.

7 Milk chocolate

At this point the chocolate can either become the dark or milk variety. To produce milk chocolate, the pressed liquor is mixed with milk and sugar and pressed again before being placed in an evaporator to produce chocolate crumbs.

A brief history of chocolate

Exactly when humans first reaped the benefits of the cacao plant is still unclear today. Anthropologists from the University of British Columbia have found evidence that *Theobroma cacao* plants were grown for food in what is now Ecuador over 5,000 years ago – nearly 1,500 years earlier than previously thought. Remnants of cacao plant DNA found on artefacts indicate that members of the Mayo-Chinchipec culture processed the beans for drinking, medicine or as a stimulant.

It's well known that the Mayans enjoyed the chocolaty character of cacao beans, fermenting, roasting and stewing them to produce an ancient drinking chocolate called 'chocolatl'. The Aztecs also recognised the value of cocoa beans, using them as money.

Regardless of its exact origin, Western explorers soon discovered cocoa's sweet potential, and by the 19th century these magic beans were transformed into solid chocolates to be sold to eager consumers.

This Aztec sculpture depicting a man carrying a cacao pod dates back to 1440–1521



4 Milling

Once roasted, the shell exterior of the beans needs to be removed. To do this a mill is used to crack and open the 'nibs' inside while a fan is used to discard the shells.

5 Grind

The remaining nibs are crushed and ground together to form cocoa liqueur or mass, which is a bitter chocolate paste.

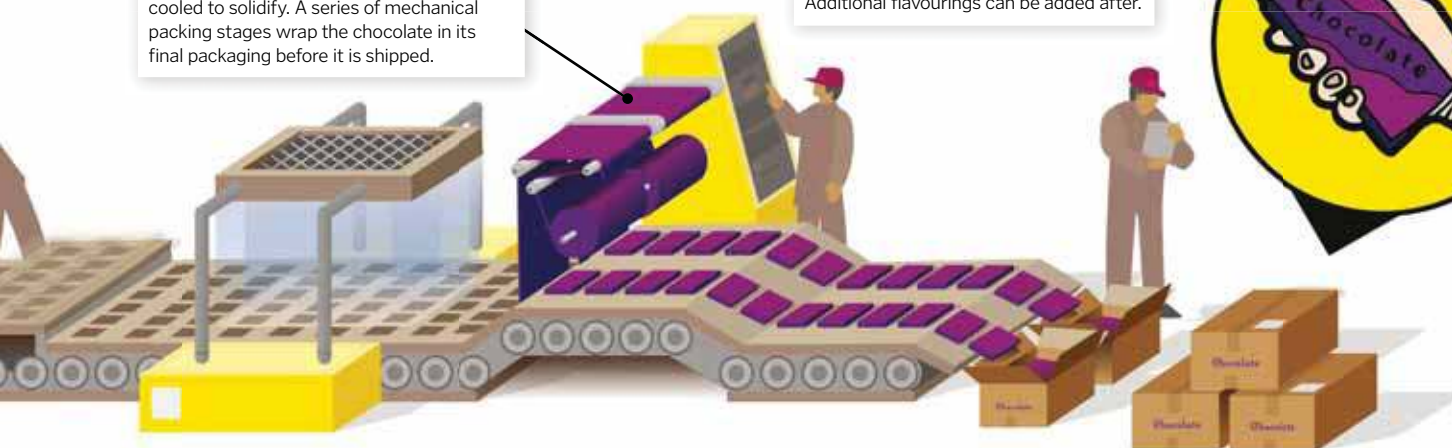


11 Packaged

Tempered chocolate can fill a variety of different mould designs, after which it is cooled to solidify. A series of mechanical packing stages wrap the chocolate in its final packaging before it is shipped.

8 Flavour

These crumbs are then rolled and squeezed to make them smooth. Additional flavourings can be added after.





Innovations in chocolate

How are food technologists bringing this household favourite into the future?

Heat-resistant chocolate

Back in 2012, Cadbury developed a new type of chocolate that could tolerate the temperature of warmer climates. This chocolate can withstand temperatures up to 40 degrees Celsius for three hours thanks to a change in the conching stage of production that further decreases the size of the sugar particles within the chocolate.

Since 2012 many manufacturers have gone on to develop different ways to help prevent sticky chocolate fingers. One of them is snack company Mondelēz, who have patented a technique for producing heat-tolerant chocolate using surfactants mixed in during the conching process. Surfactants, or surface-active agents, allow the chocolate to maintain its shape when exposed to higher temperatures.



The days of sticky fingers could be over thanks to heat-resistant chocolate



Cacao pods are being ravaged by disease worldwide

Genetically engineered chocolate

One of the biggest threats to the chocolate industry is the increased level of *Theobroma cacao* plants that are becoming infected by disease. Around one-fifth of cacao pods are ravaged by disease before they can be harvested. Researchers at Pennsylvania State University believe genetic engineering with the CRISPR-cas9 technique could provide a solution.

This would work by removing the genetic sequence in the plant's DNA that suppresses its ability to fight infection. After artificially infecting engineered leaves, the plants appeared to be more successful in fighting disease, however, the team will still need to wait for the entire tree to grow and test its fruit before they will know if the process has worked.



Ruby chocolate

Though there is a myriad of flavours of chocolate on the market, at the basic level there are three types of chocolate: milk, white and dark. However, in 2017 chocolate masters at Barry Callebaut created a fourth type of chocolate with a pink finish.

Without the addition of any colourings or fruit flavours, this new type of chocolate is made from ruby cocoa beans to give its unique pink colour and fruity taste. The method of its production is shrouded in mystery.



3D-printed chocolate

3D printing is revolutionising nearly every aspect of production that we see today, and it is now being used for new culinary creations. In the same way plastics are printed in layers from computer-aided design (CAD) software, chocolate can be put through a printer to create customisable goodies.

To do this, tempered chocolate is loaded into a syringe and continually heated to around 30 degree Celsius while the printing is carried out, thereby maintaining its semi-fluid state. As the chocolate hits the plate it begins to cool at around 20 degrees Celsius, with each layer drying as the next one forms on top.

A scanning electron micrograph (SEM) showing several large, porous, spherical sugar crystals. These crystals have a honeycomb-like internal structure with many small, interconnected voids. They are surrounded by numerous smaller, solid-looking spherical particles of varying sizes. The background is dark, making the light-colored sugar structures stand out.

Reduced sugar

Though it's what we love about the taste of chocolate, its sweetness and high sugar content means it is not a particularly healthy snack choice. The desire for 'healthy' chocolate has inspired chocolate manufacturer Nestlé to produce a 'structured sugar', reducing their sugar content in chocolate by as much as 40 per cent.

Spraying milk, sugar and water into warm air produces a substance similar to the sugar used to make cotton candy. The structured sugar is more porous than typically used sugars and therefore dissolves on the tongue faster.

Rather than simply reduce the amount of sugar in chocolate, Nestlé have engineered the sugar crystals to form in a different way to reduce their presence even more. The company has recently used this method to create their Milkybar Wowsomes treats, the first of many that will contain less sugar.

Structured sugars are porous and resemble the sugar of candyfloss



Inside the iPhone XS Max

We take a look under the hood of the biggest iPhone yet

Apple famously debuts its new iPhones in autumn each year, and now that consumers can get their hands on the new iPhone XS Max, we thought it was a great time to take a look at the technology inside this powerful new phone.

The big news for iPhone fans this year is the size of the XS Max. The 6.5-inch OLED display is the largest on any iPhone, and because it's an OLED display it has deeper blacks, vivid colours and HDR to make dark and light areas clearer. The display extends close to the edge of the glass face of the iPhone, and the back is made of glass too, which is perfect for the wireless charging that the phone offers.

The cameras have also been upgraded this year. You'll find two 12MP lenses on the back, each with larger sensors, and a 7MP TrueDepth camera on the front, which has been built for Face ID, as well as better photos and amazing augmented reality (AR).

Then there are the chips that power the phone. The A12 bionic chip has a four-core GPU that's 50 per cent faster than the iPhone X, a six-core CPU, and an eight-core neural engine. This dedicates machine learning to all kinds of features of the phone, from AR to photography – effectively, this new phone helps you to take better photos.

It's all wrapped up in a machined stainless steel casing with durable glass. It's more water- and dust-resistant too, and it comes in three colours, including gold for those feeling flashy.

The new neural engine means that you'll be able to have incredible AR experiences just by holding up your phone

OLED display

This 6.5in OLED packs in more than 3 million pixels at 2688x1242. That means there are 458 pixels per inch. Impressive.

The chassis

The rear of the phone holds the back glass in place, and all the other components attach to it, meaning that if you break the back glass it's tough to replace.

Opening up the iPhone XS Max

What's new in this year's addition to the Apple family?



Taptic engine

Apple have solved the problem of physical feedback; when you press the phone a tiny vibrating motor buzzes. This is it!

It comes in three colours, and the screen goes to the edge of the glass – except for a notch at the top

Double camera

One camera is wide-angle for normal shots, while the other offers 2x telephoto zoom. They combine to create lovely depth of field effects.

Face ID

The Face ID sensor uses infrared light – reflected off your face – to check that you're looking at your phone before it logs you in.

"The neural engine dedicates machine learning to all kinds of features"

TrueDepth camera

You get a huge 7MP front-facing camera on the new iPhone – perfect for selfies. It can do fun AR stuff too, like put a chicken head on your body.

Battery

This 12.08Wh battery uses two cells in an 'L' shape. That delivers up to 65 hours of wireless music, and it'll charge up to 50 per cent in 30 minutes.

Communication chips

This larger board holds things like the chip that controls Wi-Fi and Bluetooth, as well as the charging chips that help regulate power.

The brains

This tiny board holds the main A12 Bionic processor, along with the flash storage. You can get 64GB, 256GB or a massive 512GB of space.

Loudspeaker

This speaker pumps the sound out the bottom of the phone. The top earpiece does the same in order to produce a stereo listening experience.

Memoji

One of the more fun updates with iOS 12 on the iPhone X, XS, XS Max and XR is the ability to create your own customisable emoji using the TrueDepth camera. These characters, which Apple calls Memojis, can be given a whole host of characteristics and styles. Whether you want to create an emoji version of your own face or a strange creation with green skin and pink hair, you can do it. The tools let you add things like hats, glasses and facial hair, and you can then use the camera to pull faces, wink or even stick out your tongue. These characters can then be used to take photos with the selfie camera or during a FaceTime call to your friends.



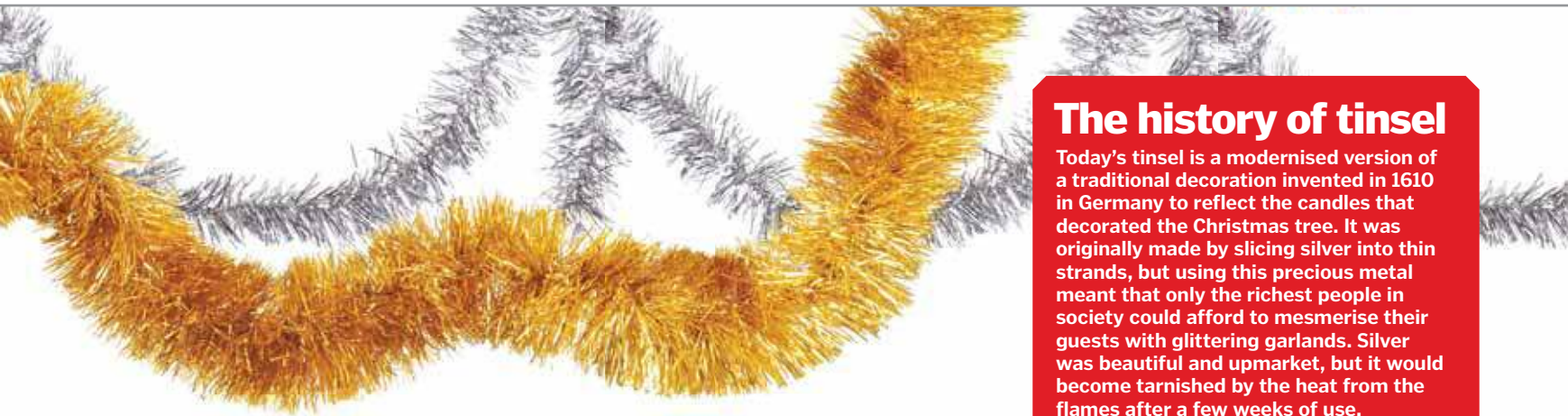
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How tinsel is made

Find out how factories produce these glittery garlands

Golden baubles, glittering silver stars, the red and white stripes of decorative candy canes – it's that time of the year again! For many families around the world, December is the time to take down the Christmas decoration box and start to adorn a festive tree, and one of the most iconic decorations is tinsel. The bits of metallic multicoloured plastic are fashioned into garlands, wrapped around staircase bannisters and hung from ceilings. Traditionally, tinsel was crafted by hand from strips of metal, but today this process has been replaced with an almost entirely mechanised method of production.

The material has also changed to keep up with the increased demand for Christmas decorations. Instead of strips of metal, most tinsel today is made from a synthetic polymer called polyvinyl chloride (PVC), but there are

also biodegradable options on the market that are more eco-friendly.

When it comes to producing this festive favourite, the first step is to pass sheets of metalised PVC through a cutter to be shredded into strips. These are then pulled through rollers, where a wire is attached to the sliced pieces to hold it all together. The tinsel moves into a tub to be spun together to create the layers of feathered material. It's then cut into lengths on a calibrated cutting wheel and shipped out to stores ready for us to pick up.

"Tinsel was originally made by slicing silver into strands... only the richest could afford it"

The history of tinsel

Today's tinsel is a modernised version of a traditional decoration invented in 1610 in Germany to reflect the candles that decorated the Christmas tree. It was originally made by slicing silver into thin strands, but using this precious metal meant that only the richest people in society could afford to mesmerise their guests with glittering garlands. Silver was beautiful and upmarket, but it would become tarnished by the heat from the flames after a few weeks of use.

People started to make tinsel from cheaper materials, such as copper, partly to make it more affordable and partly to prevent the problem with tarnishing. But when World War I started copper began to increase in value. Manufacturers trialled other materials, but after a series of fires caused by aluminium and poisoning from lead, manufacturers stopped using metal. By the 1980s polyvinyl chloride had become the material of choice as it was less flammable and non-toxic.



Machines have been used since the early 20th century as part of the tinsel-making process

Tinsel production line

Making tinsel has become a seamless process



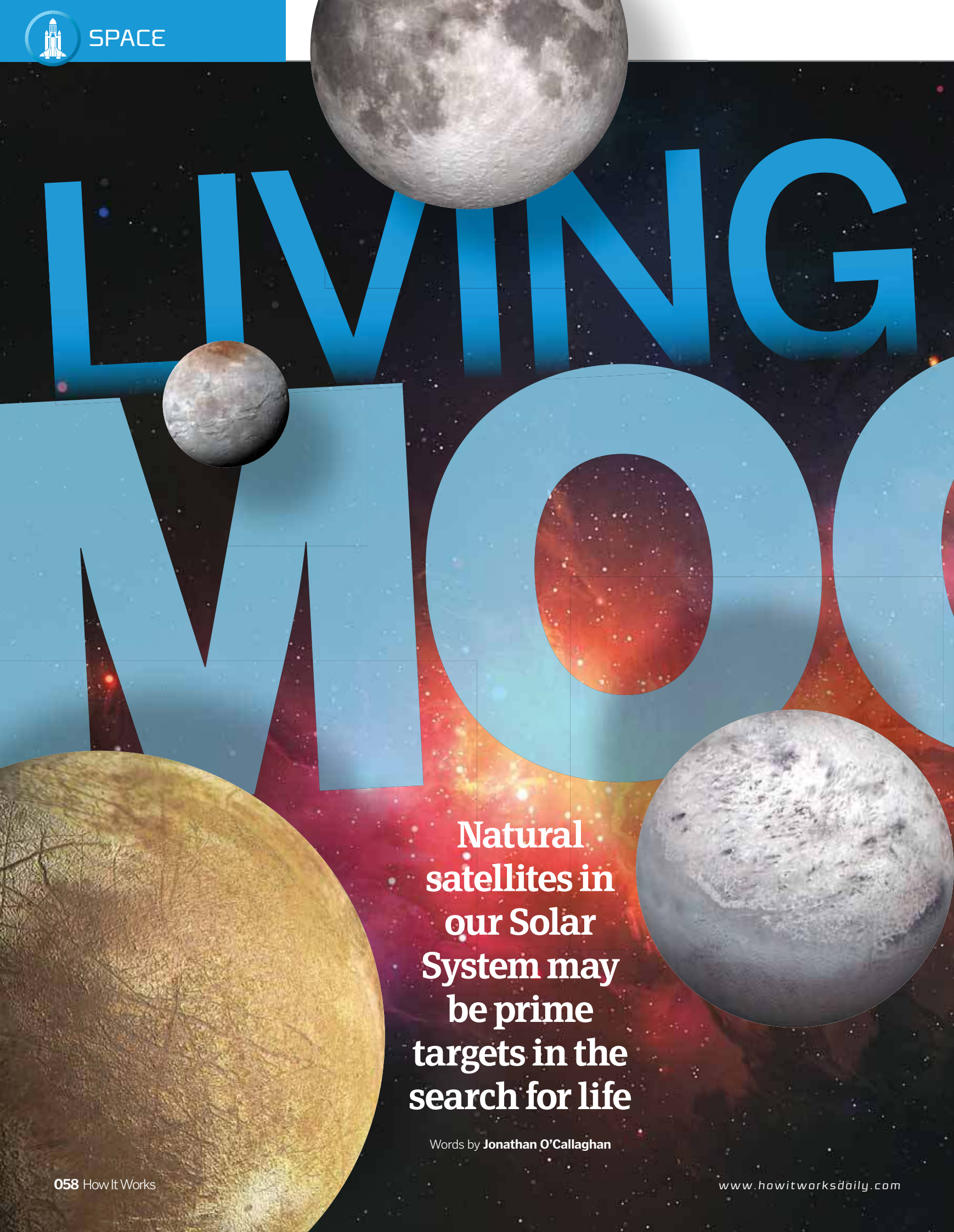
1 Tinsel town
Rolls of PVC are stacked waiting to be moved through the slicing machines to cut it into strips.



2 Gluing the glitter
The sliced PVC is fed into a spinning machine, which attaches it to a sturdy wire.



3 Chopped and shipped
The decorations are wound through a cutting wheel to cut them into lengths before packaging.



**Natural
satellites in
our Solar
System may
be prime
targets in the
search for life**

Words by **Jonathan O'Callaghan**



The search for life in our Solar System has taken many twists and turns over the decades. Once, Mars was deemed the most plausible location for past and present life, while even worlds like Venus bear the hallmarks of having been habitable. In a change of course, much of the focus today is on new locations that hold considerable promise – the moons of the outer planets, where icy surfaces and other features may hide life-harboring environments.

NASA's Pioneer 10 and 11 spacecraft in the 1970s were the first to return close-up images of Jupiter, Saturn and their moons, setting in motion a thrilling scientific story that is moving forwards at full pace today. Whereas our own Moon seems mostly devoid of life, early spacecraft like these, and the

subsequent Voyager spacecraft, showed there were plenty of secrets awaiting our discovery.

It wasn't until NASA's Galileo spacecraft arrived at Jupiter in 1995, and their Cassini spacecraft at Saturn in 2004, that excitement really started to ramp up. These probes showed those moons were far more exciting than we could have imagined, with evidence mounting that some could harbour oceans beneath their surface. While none seemed to possess any signs of life on their surface, underground – safe from radiation – scientists started to wonder what could be going on.

Fast-forward to today, and the moons of Jupiter and Saturn, and perhaps other moons too, like Neptune's Triton, are looking like the best bet in the search for life in the Solar System. Using radar and other images, we

have almost conclusively proven that locations like Europa and Enceladus house oceans beneath their surface. These oceans are thought to be tens of kilometres under the ice of their respective moons, too deep for us to reach with current technology. But Europa and Enceladus in particular seem to be firing plumes from their oceans into space, with some of that material available to study either in space or on the surface.

The Cassini spacecraft was actually able to fly through the plumes of Enceladus and thereby sample its interior. When the mission was designed, however, these plumes were not known about, so the instruments available to study them were limited. Future missions could investigate these plumes even further and look for organic compounds or

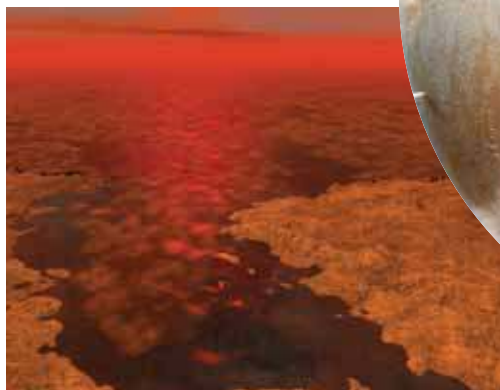


As these moons are pushed and pulled by the intense gravity of their host planets they experience tidal heating, melting the vast swathes of ice into the liquid we think resides there today. This liquid is thought to be bountiful – some of these living moons are believed to contain more water than there is on Earth. This tidal heating is interesting for another reason too. Life as we know it needs several key ingredients to thrive, including liquid water, heat and energy. It might be that on some of these moons this gravitational effect heats the cores, forming hydrothermal vents on the ocean floors. On Earth such vents provide not only heat for life but energy and sustenance too. Could it be that some of these moons, deep in their interiors, are similar to Earth?

It's not just the oceans that are interesting, as Saturn's moon Titan is intriguing for a whole other reason. While we think this moon may have an ocean underground, it's what is taking place on the surface that has scientists talking. Titan is the only world other than Earth known to have bodies of liquid on its surface – here in the form of liquid methane and ethane, creating a jet fuel-like liquid. Add in its thick atmosphere and a climate system not too dissimilar to our own, and Titan starts to tick a lot of boxes.

If life does exist on the surface of Titan, it is likely life as we don't know it, relying on processes that we don't yet understand. Much of the focus on the ocean moons, meanwhile, has been based on life as we do know it, which makes sense; we know life exists on our planet in certain conditions, so why would we not look for those same conditions elsewhere?

To get answers to these questions and more, a number of spacecraft are now being designed that could probe these moons like never before. NASA's Europa Clipper, for example, will study the moon it is named after in detail. Launching in the mid-2020s, it will try to work out how thick Europa's icy sheet is and whether there are signs of habitability on it.



Radar images suggest Titan has lakes and seas on its surface

Inside the moons

Why each of these worlds could be habitable

TITAN

Diameter **0.4 Earths**

Mass **0.02 Earths**

Atmosphere **Nitrogen (98.4%), methane (1.4%), hydrogen (0.2%)**

Titan is the only world in the universe other than Earth that we know for certain has bodies of liquid on it – in this case lakes and seas of methane and ethane, similar in composition to jet fuel. But while it might lack water, the thick atmosphere of this moon of Saturn, coupled with its Earth-like topography, makes it a tantalising prospect for life. In fact, some scientists think it might be similar to early Earth billions of years ago, when life was just starting to arise. What's more, Titan also appears to have a salty ocean below its surface. So even if the surface is inhospitable or perhaps plays host to more exotic types of life, it could be that Earth-like life can survive underground.

Ocean

Europa is thought to have a vast subsurface ocean containing more water than exists on Earth.

Tidal heating

The push and pull of Jupiter heats Europa's core, providing energy.

Icy surface

Europa's icy surface may contain material from the habitable ocean below.

Atmosphere

Titan has a thick atmosphere that protects its surface from radiation.

Ocean

Under its surface Titan may be hiding an ocean that could support life as we know it.

Early Earth

Titan's surface may resemble that of Earth billions of years ago, when life was starting to emerge.

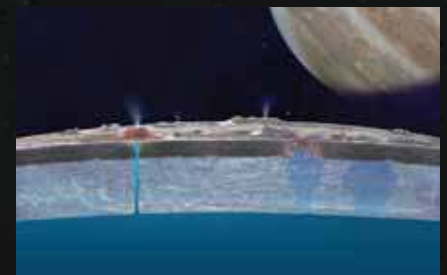
EUROPA

Diameter **0.25 Earths**

Mass **0.008 Earths**

Atmosphere **Very thin, mostly oxygen**

Europa is one of the most tantalising prospects for life in the Solar System. With a vast ocean buried beneath its icy surface, this moon is pushed and pulled by Jupiter as it orbits the planet, heating its interior and turning ice into liquid. This tidal heating effect may provide a source of energy for life in this ocean too, while vents on the seafloor – similar to those found in Earth's deepest oceans – could provide food. Oxygen, hydrogen and other compounds could also be supplied to living things from the water-ice surface, which is composed of H₂O but hit repeatedly by the intense radiation of Jupiter. This shell may also provide a shield for any life below. Questions remain unanswered about Europa that could alter its habitability. How thick is its icy shell, for example, and how long has this ocean remained under the surface, if it exists for certain?



Europa's ocean might be safely hidden from radiation under its surface

GANYMEDE

Diameter **0.4 Earths**

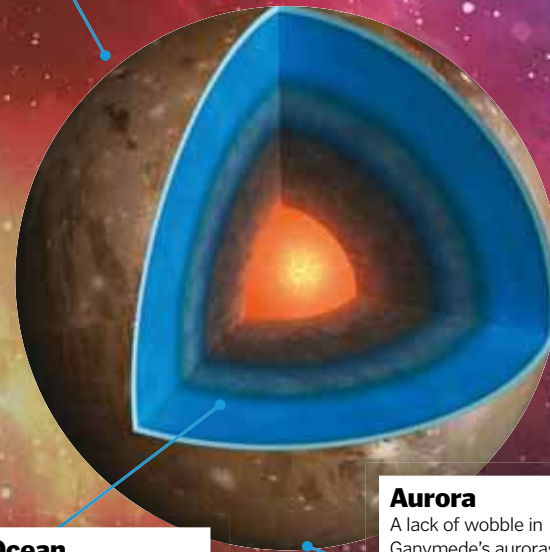
Mass **0.025 Earths**

Atmosphere **Very thin, mostly oxygen**

Ganymede is the largest moon in the Solar System, and it too is thought to have a potentially habitable ocean beneath its surface. Very little is known about this ocean though, including how deep it is or what it's made of. Tidal heating caused by Jupiter, while to a lesser degree than other moons like Europa, could be driving tectonic activity inside this moon, providing energy for life. The moon also has a magnetic field, the only moon in the Solar System known to have one. While ours is crucial in keeping life on Earth safe from radiation, no one is sure of the purpose of Ganymede's magnetism yet. Future missions will try to work out more about Ganymede's ocean and hunt for any signs of biosignatures on the moon.

Magnetic field

Ganymede is the only moon in our Solar System that is known to have a magnetic field.



Ocean

The composition and size of Ganymede's ocean isn't yet understood.

Aurora

A lack of wobble in Ganymede's auroras suggest that a subsurface ocean is keeping them steady.

OTHER POTENTIALLY HABITABLE MOONS

1 Callisto

Callisto is the most distant of Jupiter's four largest moons, and as such it receives less radiation than the others. If it contains a subsurface ocean it could be a prime habitable location.



2 Io

As the most volcanically active world in the Solar System, Io doesn't look too habitable. Even so, it may once have had liquid water, and, combined with its heat, this could have enabled life to flourish on it.



3 Triton

This moon of Neptune has a very eccentric orbit, and significant tidal heating as a result may have created an ocean of liquid water under its surface.



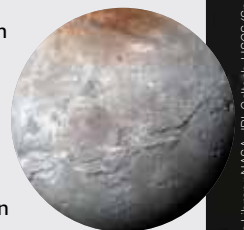
4 Dione

Saturn's icy moon Dione is also thought to have an ancient ocean that could host life beneath its surface, one found thanks to gravity data from NASA's Cassini spacecraft.



5 Charon

A canyon on Charon may suggest Pluto's largest moon once had an ancient ocean, but whether it could have been habitable is very much unknown at the moment.



ENCELADUS

Diameter **0.04 Earths**

Mass **0.000018 Earths**

Atmosphere **Water vapour (91%), nitrogen (4%), carbon dioxide (3.3%), methane (1.7%)**

Like Europa, Saturn's moon Enceladus is enticing due to the ocean that we think it's hiding beneath its icy crust. Unlike Europa, however, Enceladus is actively and regularly dumping material from this ocean onto its surface, meaning studying it may not be beyond the realms of possibility. It does this by firing out plumes from its south pole, and while we've also observed plumes on

Europa, those from Enceladus appear to erupt more regularly. Data from the Cassini spacecraft also showed that material coming from this ocean contained complex organic molecules, which may suggest the ocean is habitable. Enceladus is thought to have hydrothermal vents on its sea floor, and bubbles of gas could carry organic material from the floor to the surface. Evidence for these vents, which support life in Earth's oceans, comes from hydrogen found in plumes from the moon.

Enceladus regularly erupts plumes from its ocean into space

Plumes

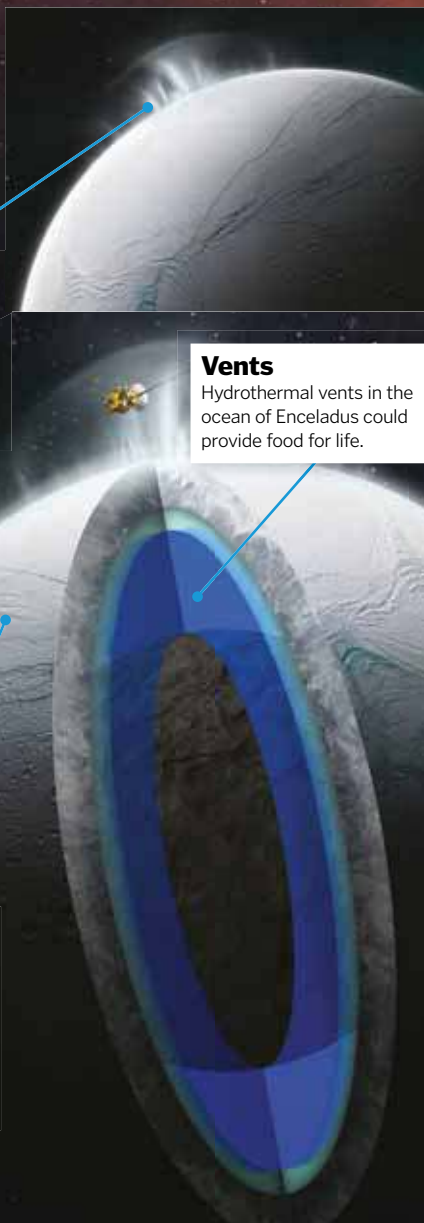
Material fired from Enceladus' ocean in plumes is easily accessible on its surface.

Vents

Hydrothermal vents in the ocean of Enceladus could provide food for life.

Organics

Organic material from the ocean could be carried up to the surface in bubbles and fired out in plumes.





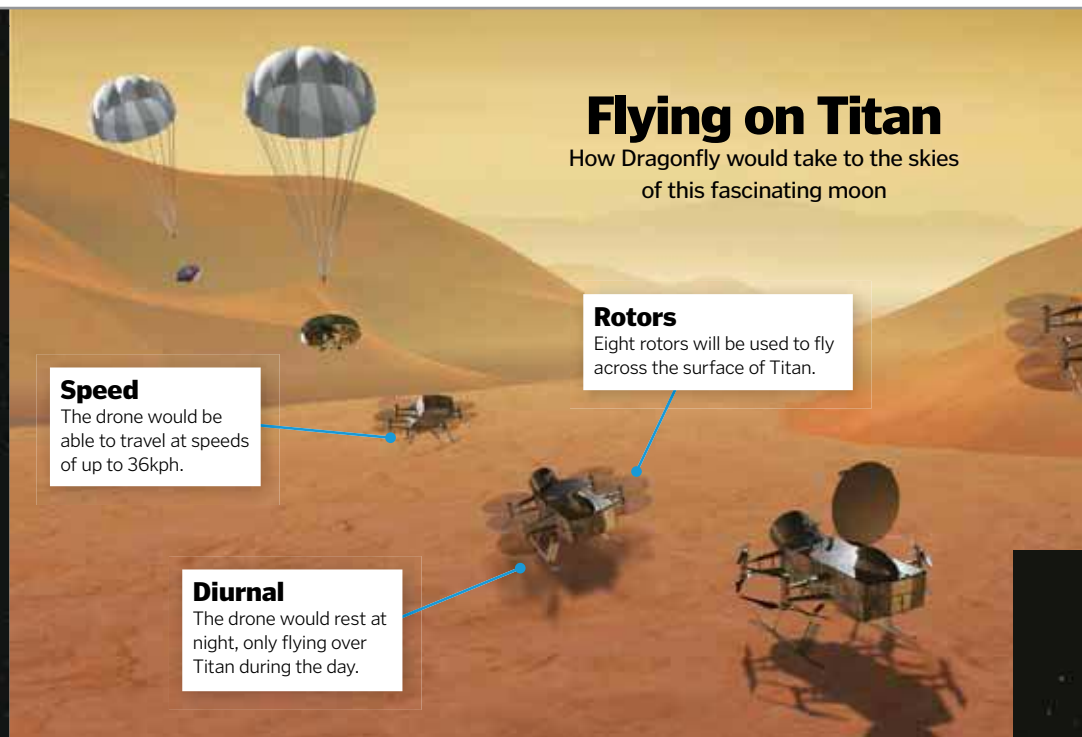
Future missions could explore the oceans of Europa and elsewhere

To complement this mission, NASA is looking to develop a Europa Lander that could land on the surface of this moon. If the plumes of Europa rain back down on the surface as we expect, then it could be possible to sample this ocean without having to drill through tens of kilometres of ice. Others argue Saturn's moon Enceladus is a better bet for such a mission, as its plumes are more constant, with more material available to study. Budgets are limited, however, so for now Europa is in the limelight.

Another mission, the European Space Agency's (ESA) Jupiter Icy Moons Explorer (JUICE), will also be investigating this system. Aside from just Europa, it will study Jupiter's other interesting moons, including Ganymede and Callisto. The latter may hide an ancient ocean that has existed long enough to allow life to take hold, whereas the former is the only moon in the Solar System known to have a magnetic field. Earth's magnetic field protects us from radiation; perhaps Ganymede's makes it similarly suitable for habitation.

The search for life in the universe is progressing steadily, with some scientists favouring a closer look at Mars, which may have once been more like Earth with seas and oceans on its surface. Others favour studying worlds beyond our Solar System, called exoplanets, to look for some that may be similar to our own. But the moons of the outer planets are without doubt among the most promising targets at the present time.

We still know very little about their oceans and potential habitability, but in the next couple of decades we might get closer than ever to finding out if life in our Solar System is limited to our own rocky planet or is spread abundantly on worlds like and unlike Earth.



Flying on Titan

How Dragonfly would take to the skies of this fascinating moon

Speed

The drone would be able to travel at speeds of up to 36kph.

Rotors

Eight rotors will be used to fly across the surface of Titan.

Diurnal

The drone would rest at night, only flying over Titan during the day.

EUROPA CLIPPER

Destination **Europa** Status **Estimated launch 2022 to 2025**

NASA's Europa Clipper spacecraft is a bold proposal to perform the most in-depth study of Jupiter's icy moon yet. By making dozens of flybys of Europa, the spacecraft will repeatedly swoop past the surface as low as just 25 kilometres. The spacecraft is designed to map the surface of Europa, while it will also use a radar instrument to work out how thick its icy shell is. It will also look for signs of plumes of warm water

erupting from the surface and try to examine the particles in the moon's thin atmosphere. There have also been suggestions the spacecraft will carry a lander too, although that might now become a separate mission. The big uncertainty is what rocket will launch the Clipper – either NASA's much-delayed Space Launch System (SLS), or perhaps another vehicle all together.

Europa Lander

How a probe could land on the surface of Europa and study this icy moon

Spiky surface

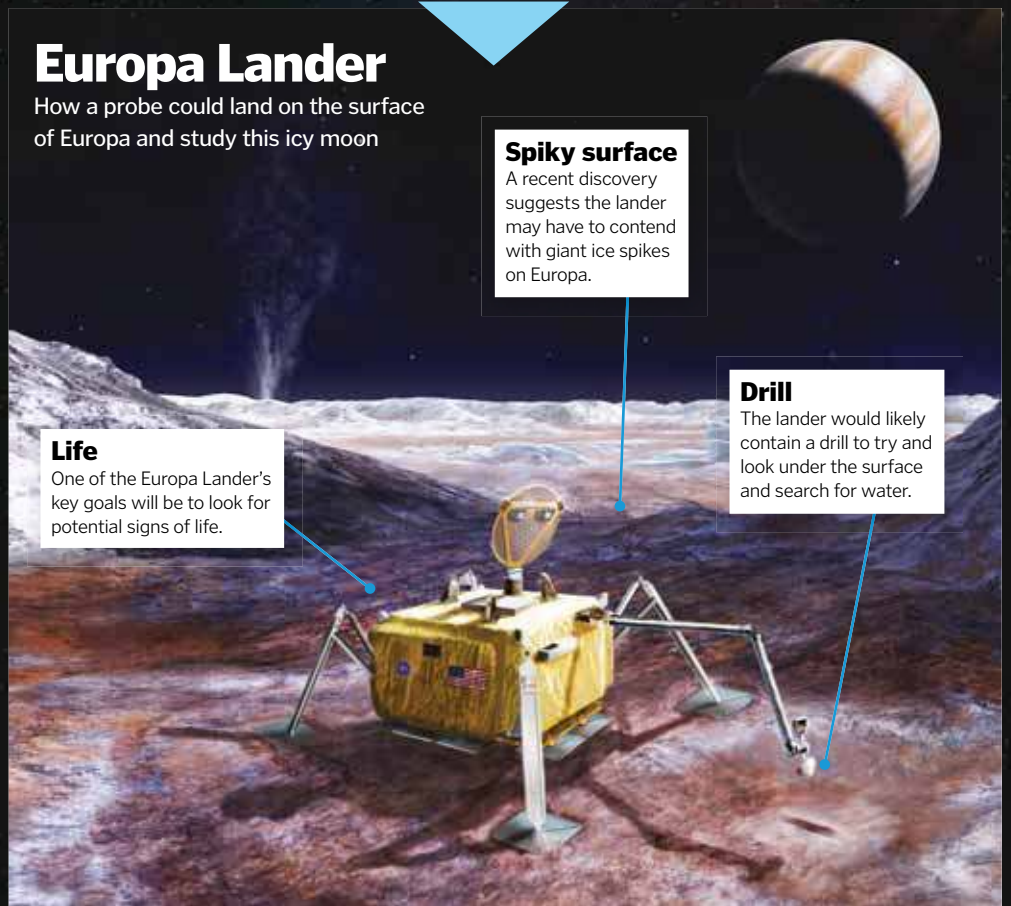
A recent discovery suggests the lander may have to contend with giant ice spikes on Europa.

Life

One of the Europa Lander's key goals will be to look for potential signs of life.

Drill

The lander would likely contain a drill to try and look under the surface and search for water.



DRAGONFLY

Destination **Titan** Status **Concept stage**

An exciting NASA concept released last year was Dragonfly, a proposal to send a drone to the surface of Saturn's moon Titan. Using eight rotors, the drone could fly across the surface, visiting multiple sites spread out at vast distances across the moon rather than a single smaller area afforded by a rover or stationary lander. Powered by a small radioactive fuel source, Dragonfly would make use of Titan's thick atmosphere to fly, studying the geology of the planet and even looking for signs of life. If it does get approved, the mission's proposers say it could launch in 2025 and arrive at Titan in 2034, lasting for a few years on the surface.

Altitude

The drone would be able to fly up to 4km above the surface.

Inside JUICE

How this European spacecraft will study Jupiter and its moons

Ice

A spectrometer on the spacecraft will study the ice on the moons of Jupiter.

Camera

The camera on the spacecraft will take detailed images of each world.

Radar

JUICE will use an ice-penetrating radar to work out how deep the oceans are on the moons.

Some moons may have hydrothermal vents similar to those on Earth

"The search for life in the universe is progressing steadily"

Was Earth's Moon once habitable?

While much of the focus for habitability is on the icy moons in the outer Solar System, our own Moon could be a surprising target too. Findings suggest that its rocks are richer in water than we thought, and it's estimated that about 3.5 billion years ago it had an atmosphere about one per cent as thick as ours, thereby thicker than that on Mars.

Put this all together and scientists think the Moon could have supported liquid water for millions of years around this time, during a period when life on our own world – which was possibly delivered by comets or asteroids – was only just starting to develop.

It could be that life on Earth spread to the Moon via meteorite impacts, a process called lithopanspermia. But there are no clear signs of bodies of ancient water on the Moon, so this idea will require further investigation in future.



The young Moon could have supported water for a short amount of time

JUICE

Destination **Jupiter and its moons**

Status **Estimated launch 2022**

The ESA's Jupiter Icy Moons Explorer (JUICE) will provide a vast amount of data about the gas giant and its moons, in particular focusing on those moons we think might have oceans under their surface. The mission will try to work out if it's possible that any of the moons are habitable, particularly Ganymede, Europa and Callisto. It will map the surfaces of these worlds and study their interiors, including looking for organic molecules on Europa that may be indicative of life. It's also going to try and understand more about how Jupiter works, to see if on a long time scale it has created a stable environment for its moons. Arriving at Jupiter in 2029, the spacecraft will orbit the planet until 2033, when it will enter orbit around Ganymede.



Return to the Moon: Chandrayaan-2

India's next lunar mission will probe new areas of the Moon with an exciting trio of tools

Chandrayaan-2 is the Indian Space Research Organisation's (ISRO) second mission to the Moon, with this latest project tackling lunar exploration in more extensive fashion. Although the launch was scheduled most recently for October 2018, due to some important changes that needed to be made to the mission it will be launched no earlier than January 2019 – with the window open until March – from the Satish Dhawan Space Centre in Sriharikota, Andhra Pradesh, southeast India.

The purpose of this mission is to study the mysterious Moon from top to bottom, including its topography, mineralogy, exosphere, elemental abundance and even possible seismic activity. With seven

instruments aboard the orbiter, three aboard the lander and a further two attached to the rover, there will be no stone left unturned.

Whereas Chandrayaan-1 was just an orbiter, Chandrayaan-2 has an orbiter, lander and rover, providing the full exploration package. Once launched on the tip of the Geosynchronous

Satellite Launch Vehicle Mark III (GSLV Mk III), in just over a month the Chandrayaan-2 orbiter will be placed into orbit 100 kilometres above the lunar surface. Once settled, the orbiter's cameras, spectrometers and radars can get to work in finding the elusive lunar water ice and hydroxyl (molecules containing the oxygen and hydrogen bond) signatures. After this the lander will disengage and undergo a soft landing near

the southern pole of the Moon, territory previously untouched by humans or even human-made objects.

This lander has a unique science payload, as it contains a thermophysical experiment to measure the surface's thermal properties, an instrument designed to study the surface's ionosphere and

atmosphere, and lastly a seismic activity instrument, which will allow scientists to delve deeper into the Moon than any other instrument before. After its (hopefully) successful landing, the rover will be deployed from the lander, releasing the mini-tank of scientific adventure onto the lunar surface.

"Chandrayaan-2 has an orbiter, lander and rover, providing the full exploration package"

What about Chandrayaan-1?

The launch of Chandrayaan-1 in October 2008 was a historic day for Indian space exploration, as it was a sign of the nation's technological advancement and ambition to play its part in the quest to discover the secrets of space.

Chandrayaan-1's main component was its orbiter, which was placed into an elliptical orbit around the Moon's poles on 8 November 2008. Just six days after orbital insertion the orbiter released its Moon Impact Probe, painted with the Indian flag, went crashing into the lunar south pole, making India the fourth nation to land a probe on the Moon.

The results from Chandrayaan-1 were vital in the search for water on the seemingly dry Moon. An onboard instrument made by NASA called the Moon Mineralogy Mapper found important evidence for water or hydroxyl on the surface, a key discovery that was announced in September 2009.

One month prior to the announcement, Chandrayaan-1 stopped communications due to a series of technical issues. Although it failed to survive the intended two-year duration, it completed 95 per cent of its planned objectives.



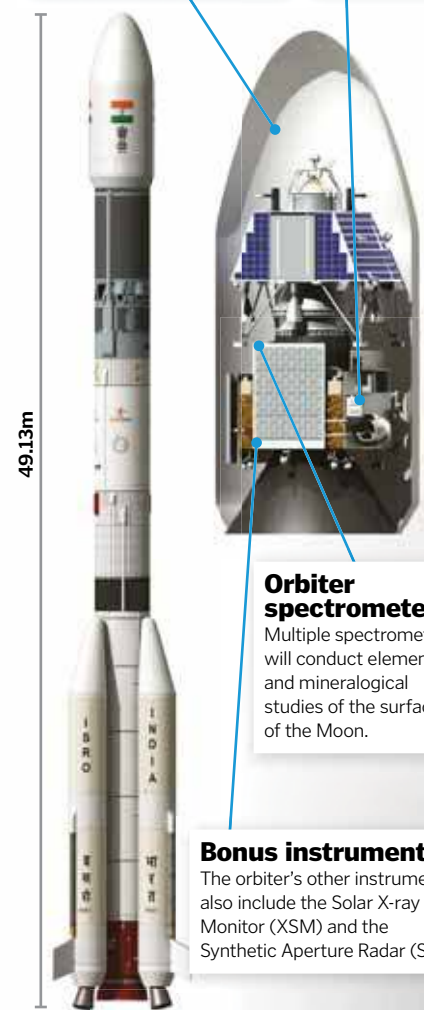
Chandrayaan-1's Moon Mineralogy Mapper helped confirm the presence of water ice on the Moon

Orbiter cameras

There are two main cameras on the orbiter: the Terrain Mapping Camera 2 (TMC-2) and the Orbiter High Resolution Camera (OHRC).

Total payload

The trio of components will collectively weigh 3,877kg and they will be stowed at the tip of the GSLV Mk III launch system.



49.13m

Orbiter spectrometers

Multiple spectrometers will conduct elemental and mineralogical studies of the surface of the Moon.

Bonus instruments

The orbiter's other instruments also include the Solar X-ray Monitor (XSM) and the Synthetic Aperture Radar (SAR).

The Vikram Lander

The mission's lander was named after Vikram Sarabhai, widely considered to be the father of the Indian space programme.





Chandrayaan-2 is shown here in a clean room at the ISRO Satellite Centre



Chandrayaan-2 will be launched into a similar orbit to its predecessor, Chandrayaan-1 (pictured above)

What's to come from Chandrayaan-2

There are many aspects to look forward to ahead of the spacecraft's launch in early 2019

Lander instruments

The lander will gather data on seismic activity, thermal properties and the ionosphere and atmosphere.

Instruments for inspection

The two instruments onboard the rover are the Laser-Induced Breakdown Spectroscope (LIBS) and an Alpha Particle X-Ray Spectrometer for closer inspection of the lunar surface.

Lunar landing site

Chandrayaan-2 will land further from the Moon's equator than any other mission before it.

Mini-tank rover

Featuring six independently motorised wheels, with the corner wheels steering, the lunar rover will move more like a tank.

Lander cameras

Multiple cameras are fitted to the lander, which will help to guide it down during its descent to the landing site.

5 FACTS ABOUT THE FUTURE OF INDIAN SPACE EXPLORATION

1 Aditya-L1

Due to be launched around 2021, Aditya-L1 will be positioned in the gravitational 'parking spot' Lagrangian point 1 (L1), where it will study the Sun's photosphere, chromosphere and corona.

2 AVATAR

The Aerobic Vehicle for Transatmospheric Hypersonic Aerospace Transportation (AVATAR) is a conceptual single-stage reusable spaceplane that can perform a horizontal take-off and landing – a unique ability among spacecraft.

3 Venusian Orbiter

This proposed orbiter will study the atmosphere and surface of Venus and – if funded – it could see space in the early 2020s.

4 NISAR

The joint project between NASA and ISRO, named the NASA-ISRO Synthetic Aperture Radar (NISAR), will provide the first radar imaging of natural processes occurring on Earth.

5 Mars Orbiter Mission 2, or Mangalyaan 2

After the great success of the first Mars Orbiter Mission – the first nation to reach Mars' orbit on its first attempt – there is a second in the pipeline scheduled for around 2022-2023. This orbiter will continue to study Mars at great depth, with talks of a lander and rover being involved also.



The Christmas star

Arguably one of the most talked about astronomical events throughout history, was the star of Bethlehem even really a star?

It's said to have guided three magi, or wise men, to the birth of Jesus Christ around two millennia ago, however, the origin of the guiding light of the star of Bethlehem, also known as the Christmas star, could have several astronomical explanations.

The magi were three ancient astrologers and studied planets and stars as a way to explain the events on Earth, such as the birth of a new king. Nowadays, there are many theories alluding to the possible origins of the 'star', such as a planetary alignment, a supernova or a comet, just to name a few.

With only the Gospel of Matthew in the New Testament as a reference, there are just a few details available for modern astronomers investigating the supposed star. It is said that the magi were guided to Bethlehem by a light that appeared from the east and then reappeared in the west. This suggests that the source could have been a nova or supernova explosion, which would produce a bright light and be an unfamiliar sight in the sky. There is, however, a flaw in the nova/supernova theory: astronomers today can see no sign of a nebula that would be found in the wake of ancient exploding stars from that particular time.

Planetary conjunctions may also offer an explanation due to their rarity and their pattern of movement in the sky. A comet recorded by ancient Chinese astronomers circa 5 BCE could

be another cosmic candidate for the guiding light mentioned in the Bible.

Scholars have yet to agree on an astronomical explanation for the star of Bethlehem, but theories are continually being re-evaluated and maybe one day they will reach a conclusion.

What did the wise men see?

Astronomers have a number of theories



1 Comet

The star of Bethlehem is often depicted as a shooting star or meteorite, but these were seen as bad omens, making it unlikely the magi would follow it. Halley's Comet did appear in the night sky in about 12 BCE – a few years before when some historians think Christ was born.

LIKELIHOOD: **Unlikely**



The three magi are said to have travelled to Bethlehem to witness the birth of a king, guided by a star... or was it?



2 Planetary conjunctions

Planets were believed to foretell events, and a rare planetary conjunction would have been noted by the magi. It is believed such an event occurred in 6 BCE when Jupiter, Saturn, the Moon and Sun aligned. Jupiter's retrograde movement in the west possibly led the magi to Bethlehem.

LIKELIHOOD: **Possible**



3 Regulus, Jupiter and Venus

Using the same logic, a planetary conjunction being the true source of the 'star' of Bethlehem may be an answer. Around 2 BCE, Jupiter, Venus and the star Regulus converged in the sky. However, this may have occurred too late to coincide with Jesus' birth between 6 to 4 BCE.

LIKELIHOOD: **Possible**



4 Heliacal rising

This is the result of a star (or another celestial object like a galaxy), previously hidden behind our Sun, briefly rising from the east before sunrise. It is thought the heliacal rising of a star called Alpha Aquarii could have occurred at this time and be the famed star of Bethlehem.

LIKELIHOOD: **Possible**



5 Supernova

While light produced from the explosive death of a star would be bright enough to be seen in the night sky, it would offer little as a guide. Matthew doesn't mention anyone seeing the star other than the magi. A supernova would have been a spectacular sight seen by many people.

LIKELIHOOD: **Unlikely**

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HISTORY OF THE VATICAN

Nestled inside Rome, the bustling Italian capital, this tiny city-state has remained the centre of the Catholic world for centuries

Words by **Tim Williamson**

Vatican City is the spiritual and physical centre of Catholicism and the residence of the religion's head, the Pope. With a tiny population of 800 people, and guarded by the world's smallest army, the city nonetheless welcomes some 5 million visitors a year, including devout pilgrims and curious tourists from around the globe.

Since its construction began in the 5th century the city has survived destructive wars as well as several radical re-designs. The city we see today is a mere fraction of the size of the many territories previously controlled by the Catholic Church, the governing body of which is the Holy See. Historically, these Papal States made up a large portion of the central Italian Peninsula, before the unification of Italy in 1871 reduced them to essentially the confines of the Vatican walls. In its modern form the Vatican City State has existed since 1929, when the Kingdom of Italy granted its independence. In this treaty, the Holy See and the Vatican City State were defined as two distinct entities – the former is a legally recognised sovereign entity, the religious organisation, while the latter is the country itself with physical borders and a government.

The head of both the Vatican City and the Holy See is the Pope. Officially he is also known as the Bishop of Rome; Vicar of Jesus Christ; Successor of the Prince of the Apostles; Supreme Pontiff of the Universal Church; Sovereign of the State of Vatican City and more. In their role as the head of the Catholic Church, popes have used the Vatican as their residency since the 5th century. Built upon the supposed burial site of Saint Peter (one of Jesus' disciples), it holds great religious significance for Christians, and the modern building is a wonder of Renaissance architecture, filled with artistic masterpieces. However, during more turbulent times the papacy faced grave opposition, and, during the 14th century in particular, rival factions

challenged its legitimacy. Rival popes, also known as 'antipopes', were set up as challengers to the Pope in Rome, with one such reigning in Avignon (which today is in France) from 1378.

During this period the papacy was heavily involved in European politics, authorising and even taking part in wars on neighbouring states. In the 15th century Pope Julius II fortified the city with thick walls and commissioned a unit of Swiss Guard for his personal protection, a tradition that continues to this day.

Religion and faith often did not stand in the way of Europe's kings declaring war against the

Pope, and in 1527 the city came under attack and was conquered by a mutinous army of Charles V, Holy Roman Emperor. In 1808 the city was again under threat after Napoleon occupied Rome. Having annexed the rest of the Papal States, the French army even kidnapped Pope Pius VII, who remained captive until 1814.

The centuries since have witnessed the final decline of the Church's territories, and since the 20th century the Vatican City remains the only state belonging to the papacy – nonetheless, its long history and traditions remain a global fascination to millions.

Inside the Vatican

This tiny, walled city-state features iconic architecture, Renaissance masterpieces and a helipad





Saint Peter's Basilica

Today's structure is the largest church building in the world and the heart of the holy city

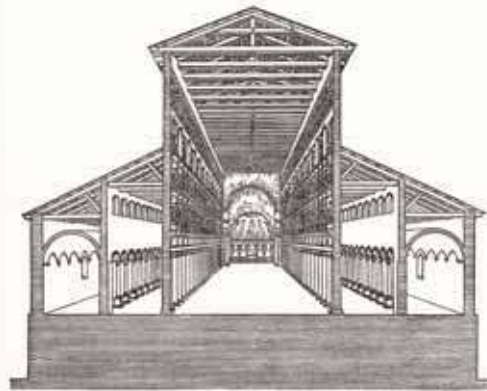
Designed and built during the 16th and 17th centuries, the present-day Basilica stands on the same site as a previous building built by Emperor Constantine in the 4th century CE. Traditionally it is built upon the site of Saint Peter's tomb – it's believed he was buried here after being executed by Emperor Nero in around 64 CE. The Circus of Nero, a huge ancient chariot racecourse, originally stood here, and Peter is thought to have been buried close by.

Centuries later, from around 320 CE, Emperor Constantine built several basilicas in Rome and its surrounds, including one on Vatican Hill, over the old Circus complex. This original, or 'Old', basilica was much smaller than its modern successor, at over 106 metres long and 30 metres high. By the 15th century the building was also in a deteriorating state, and much of the old structure had been torn down or replaced.

By the Renaissance period it was decided to overhaul Saint Peter's entirely, drawing from the ranks of genius architects and artists of the Italian Peninsula. Pope Nicholas V began this grand design in the mid-15th century, aiming to produce a far more impressive and structurally sound Basilica more suitable for the centre of the Christian world. Construction continued around the shrine to Saint Peter, which remained preserved in the centre, or transept, of the

church. Building work continued into the 16th century but stalled several times after the death of certain popes and catastrophically so when Rome was sacked in 1527.

Over the decades several architects added their own vision to the project, including Michelangelo, who in the middle of the century even had whole cloisters torn out. In 1586 the great Egyptian obelisk that had stood at the centre of Nero's Circus was painstakingly moved to the centre of Saint Peter's Piazza, and the Basilica's large dome was completed a few years later. It wasn't until 1606 that the last remnants of the Old Saint Peter's were finally torn down.



An engraving of what the original St Peter's looked like from within

View of the modern Basilica today, as seen from St Peter's Square



Another Pope

Although the Pope in Rome is the head of the Catholic Church, the Coptic Orthodox Church is an entirely separate faith founded by Saint Mark in the 1st century CE. The head of the Coptic Church is the Pope of Alexandria and Patriarch of Saint Mark, a figure who leads a worldwide congregation of over 18 million. Based mainly in Egypt, the Coptic Church observes different practices and uses its own version of the Bible.

One of the most intriguing traditions of the church is the method by which it selects each new Pope. Instead of an outright election, the successful candidate is chosen at random by a blindfolded child. This 'Holy Altar Lottery' is used, as it is believed that divine intervention determines the outcome.



A blindfolded altar boy selects a name at random to decide the next Coptic Pope in 2012



The frescoes of the Sistine Chapel are considered among Michelangelo's most important artwork



The view across Saint Peter's Square, which measures an impressive 320 metres long and 240 metres wide

The Pontifical Guard

One of the world's oldest military units, the Swiss Guards is part of a military tradition that goes back five centuries

These colourful soldiers may appear to be bringing Renaissance flair for the delight of tourists, but in fact they serve an important purpose in providing security for the Pope.

The origins of the Pontifical Guard date back to 1506, when Pope Julius II hired a unit of Swiss soldiers for use as his personal bodyguard. During this period the Papal States extended far beyond the limits of the Vatican walls, and the Papacy was often involved in conflicts with neighbouring nations. Swiss mercenaries were regarded as excellent fighters, and for the right price any ambitious prince or duke could hire a band of these elite soldiers, who could potentially be decisive on the battlefield.

However, in 1527 the Guard faced disaster during the Sack of Rome by an invading army of the Holy Roman Emperor Charles V. 189 guardsmen stood their ground to defend the Vatican and Pope Clement VII, with all but 42 killed in a brutal last stand by the shrine of Saint Peter. The guards had bought the pontiff enough time to escape through a secret passage out of the city.

While today's guard has not faced anything nearly so perilous, it maintains high standards of military training. Although they carry traditional halberds and swords, each recruit must have served in the Swiss army, with proficiency in firearms and close-combat techniques. Along with the Gendarme Corps, the Guard also provides protection for the Pope on his visits abroad.

Coloured pattern

The red, blue and yellow stripes of the uniform represent the family colours of two 16th-century popes, Leo X and Julius II.

Guard uniform

This striking outfit has origins in Renaissance warfare

Headwear

Steel morion-style helmets are worn for ceremonies and important occasions, but soft Basque caps are donned for normal duty.

Doublet

This traditional jacket is worn underneath a metal cuirass during special occasions.

Traditional dress

The design and striped pattern of the uniform was inspired by Renaissance frescoes depicting guardsmen, although a plain blue garment is worn for nighttime duties.

Entry requirements

All guardsmen must be Swiss citizens, and in addition they must learn to speak fluent Italian upon joining the unit.

Halberd

Famously wielded by Swiss mercenaries in the medieval and early modern periods, the halberd was originally designed to break through plate armour, but today it is purely ceremonial.

All male

Only men are currently allowed to join the Guard; they must be healthy and less than 30 years old.





Picking the Pope

Electing the new pontiff is a process steeped in religious ceremony, ritual and secrecy

By tradition, the College of Cardinals (called the conclave) meet to elect the new Pope, who is also referred to as the successor to Saint Peter, Christ's vicar on Earth, the Bishop of Rome, and today is the head of a congregation numbering over 1 billion people.

For centuries each conclave has gathered inside the Vatican palaces, which are locked down to prevent anyone outside the conclave influencing the vote. During the Conclave of 1484, cardinals were even forced to eat and sleep in the cramped conditions of the Sistine Chapel. Despite these measures, vote-buying and other tactics were suspected in several conclaves. The historic power struggles, alliances, factions and intrigues of European politics were often at work at these gatherings. Although no such devious dealings are known to continue in the modern era, the conclave remains a private process, with rigorous checks and balances.



Mourning

Starting from the day of the Pope's funeral, the Vatican begins nine days of mourning, with mass held on each day. The body is dressed in ceremonial robes.

The Conclave

Held behind closed doors, the papal election follows a strict and secretive procedure



Death of the pontiff

When the incumbent Pope has been declared deceased, or in rare occasions announces his retirement, the College of Cardinals are summoned to the Vatican.

The Sistine Chapel

The Conclave

After the period of mourning, 120 cardinals gather in the Sistine Chapel. The doors are locked and rounds of voting for the new pontiff begin.

Chimney smoke

Each ballot is burned on a stove along with a special dye - black denotes no majority has been reached, white to declare a new Pope has been elected.

Pope mobiles through the years

For decades the pontiff has used a range of transport solutions to keep him mobile

1878-1903

Sedan Chair - Leo XIII

During the 19th century popes would be carried around inside these highly decorated enclosed or open-air chairs by guards.



1800s

Carriage - Various

Throughout the 19th century horse-drawn carriages were used, upholstered with red velvet and decorated with gilded engravings.



1930

Mercedes-Benz Nürburg 460 - Pius XI

This model came with a bespoke crimson rear passenger seat and was even test-driven by Pius XI himself.



1965

Lincoln Continental - Paul VI

This six-metre limo came complete with a specially designed roof windshield and a crank to raise the Pope's seat higher.



1978-2005

Fiat Campagnola - Paul VI, John Paul II

In May 1981 John Paul II was riding in this open-topped 4x4 when he was shot.

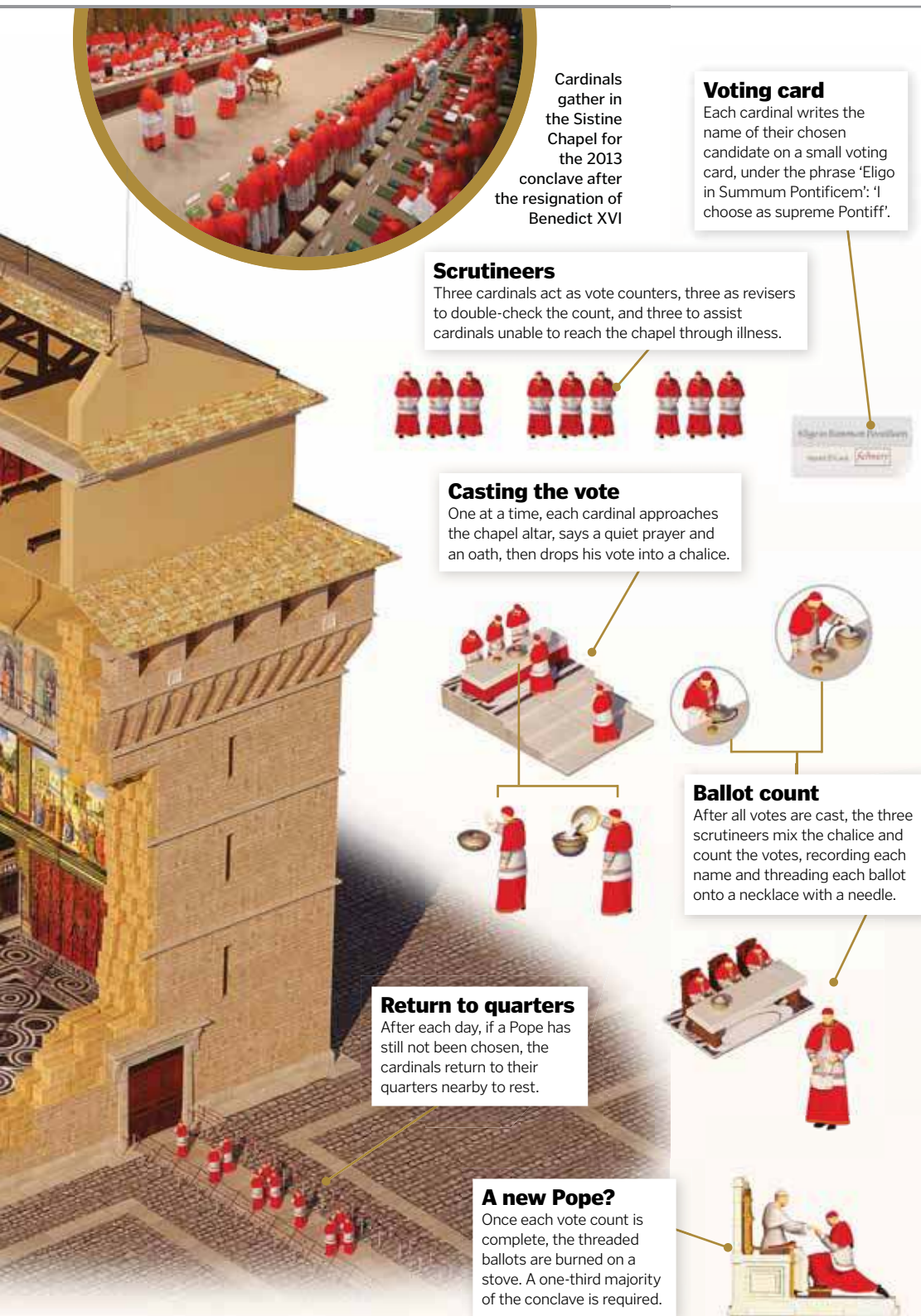


1979

Ford D-Series - John Paul II

This transformed truck is surrounded with shatterproof glass and has enough room to accommodate 16.





5 WORST POPES

Paul IV: 'The Zealot'

Creator of the Roman Inquisition, which ruthlessly hunted down and brutally punished accused heretics, Paul IV also burned hundreds of supposedly blasphemous books and also severely persecuted Rome's Jewish population.



Benedict IX: 'The Scandalous'

Made Pope on three separate occasions, Benedict engaged in multiple relationships (forbidden for priests) and even sold the title so that he could marry. After conspiring his way back into power, he was finally deposed in 1049 CE.



Leo X: 'The Greedy'

Leo enacted the sale of 'Indulgences' in the church, essentially taking payment in exchange for absolving, or reducing, the punishment for sins. This corrupt practice contributed to Martin Luther's Reformation.



Alexander VI: 'The Schemer'

Accused of bribing his way into power, Alexander also had several children and a secret wife. He made his teenage son a cardinal and used his position to strengthen his dynasty.



Stephen VI: 'The Avenger'

Stephen ordered that his dead predecessor, Pope Formosus, be dug up and put on trial for alleged corruption. He then had the body mutilated and dumped in the River Tiber.



1980-2012

Mercedes-Benz 230-G - John Paul II

The special plexiglass bubble canopy on this vehicle was later made bulletproof for extra protection.



1982

Leyland Constructor - John Paul II

Designed for the Pope's 1982 visit to the UK, this truck weighed over 21,000 kilograms and took six weeks to build.



1982

Range Rover - John Paul II

Another vehicle constructed for John Paul II's UK visit, this was among the first of the Popemobiles to feature bullet-resistant glass.



1988

Ferrari Mondial - John Paul II

While on a visit to the Ferrari HQ in Maranello, northern Italy, the Holy Father went out for a spin in a Mondial convertible.



1999

Bus - John Paul II

After serving its purpose during a 1999 visit to Mexico, this re-designed bus was turned into a permanent memorial.



2015

Jeep Wrangler - Francis

For the Pope's 2015 US visit, this robust 4x4 broke with tradition by dropping the bullet-resistant glass case.



2013 onward

1984 Renault 4 - Francis

The current Pope favours simplicity and drives himself around the Vatican in an old Renault with over 299,000 kilometres on the clock.





Toy story

Find out how the teddy bear got its name

Once upon a time in 1902, the President of the United States was hunting for bears in the woods. He had not seen a single one and the other hunters began to feel sorry for him, so they cornered and chained an old black bear to a tree. But the President refused to shoot the animal, saying it was unsportsmanlike. The news made the front page – it wasn't just any president, it was Theodore Roosevelt, the big game hunter!

Political cartoonist Clifford Berryman satirised the event, drawing the old bear as an adorable cub. Seeing the illustration, sweet shop owners Rose and Morris Michtom were inspired to make a stuffed toy bear and called it 'Teddy's Bear'. They made soft toys as a side-line business, but soon requests for Teddy Bears

were coming in thick and fast. After gaining Roosevelt's permission to use his name, the couple started mass-producing them.

Meanwhile, in Germany, the Steiff family of toy makers had produced a mohair bear with movable limbs after a trip to the zoo. They exhibited their creation at a toy fair, where an American businessman ordered 3,000. Soon, other bears were flooding the market, capitalising on their popularity. More than a century later, the teddy bear still lives happily ever after.



Clifford Berryman's famous cartoon of Roosevelt refusing to kill a black bear

5 FACTS ABOUT TEDDY BEARS

1 A record-breaking collection

Jackie Miley from South Dakota, US, has filled her home with 8,026 bears – the largest collection according to the Guinness World Records 2018.

2 Beary expensive

The priciest plush bear sold for £125,831 (\$182,550) in Monaco. It was a 45-centimetre Steiff 'Louis Vuitton' bear made in 2000.

3 Out of this world

Magellan T Bear became the first teddy bear in space in February 1995 aboard the Space Shuttle Discovery. School pupils worked with NASA to have the bear certified for spaceflight.

4 A childhood classic

The famous song *Teddy Bears' Picnic* was composed in 1907 by American John Walter Bratton, but the lyrics weren't actually added until 1932 by Irish-born songwriter Jimmy Kennedy.

5 Bears mourned the Titanic

After the sinking of the Titanic in 1912, German producers Steiff made 600 black 'mourning bears' to honour the victims. One of these rare bears fetched £91,750 (approximately \$120,000) at a London auction in 2000.

Bear necessities

A teddy bear starts out as an artist's drawing, from which paper patterns are cut out and pinned to fabric.

Button eyes

Originally, teddy bears were made from mohair fabric then stuffed with excelsior packing before black-leather shoe button eyes were fixed on.

Building a bear

Early teddies had their limbs and heads made and stuffed separately before these were stitched to the torso.



Christmas lights
decorate the market
in Vienna, Austria

Christmas markets

Unwrap the origins of this festive tradition

Glowing wooden huts, cauldrons of mulled wine, smoky cooking stoves and arrays of precious trinkets for sale – all signature sights of a Christmas market. Today it is the highlight of any seasonal shopping trip, but it is also a tradition that dates back centuries.

These stalls originated in German-speaking Europe when farmers saw an opportunity to extend their weekly markets during the Christmas period, selling meat for winter feasts. One such market was recorded as early as 1296 in Vienna, Austria.

Some of the oldest Christmas markets appeared in Munich (1310), Bautzen (1384) and Dresden (1434). Stalls were assembled in town squares and became ever more popular when the tradition of exchanging presents

evolved in the 16th century. The mythical gift-giver was the Christkind (Christ-Child), and the markets became known as Christkindlmarkt. To this day Nuremberg pays homage to the Christkind by choosing a local girl to play the part of this angelic figure on the first night of the market. The city also saw early signs of the commercialisation of Christmas – in 1616 a disgruntled priest was forced to cancel his church service when his congregation instead rushed off to browse among the enticing yuletide shops.

Over time Christmas markets have sprung up in cities across the world, but there are still signs of where it all began, as German staples such as bratwurst, glühwein and gingerbread are now as traditional as tinsel on trees.

Classic Christmas customs

Seasonal markets aren't the only tradition that began in Germany. By 1605, fir trees had appeared in the parlours of Strasburg, decorated with paper roses and sweets. Germany was also where the idea of gifts on Christmas Eve originated.

In the 16th century, gifts were exchanged on 6 December, the feast of St Nicholas. However, religious reformer Martin Luther believed there should be more emphasis on the nativity and the baby Jesus, so he proposed that Christmas Eve should be the day for gift giving. As a protestant, Luther wanted to move away from the Catholic worship of saints, so he came up with the idea of the Christkind – an angelic figure who delivers presents to children. In Germany, Christmas Eve has remained the principal day for exchanging presents ever since.



In Nuremberg, a local girl dresses as the Christkind at the opening of the Christmas market

5 FACTS ABOUT MAGICAL MARKETS



1 Dresden Striezelmarkt, Germany

Founded in 1434, this market is named after 'Striezel', an old word for stollen, a 14th-century cake.



2 Birmingham's Frankfurt Christmas Market, UK

This claims to be the largest German Christmas market outside of Germany or Austria.



3 Strasbourg, France

When the first Christmas market was held here in 1570, Strasbourg was part of Germany.



4 Marienplatz Christmas Market in Munich, Germany

This market sees hundreds of people dress up as the villain Krampus.



5 Christmas Market on Vörösmarty Square, Budapest

Expect painting, concerts and the smell of kürtoskalács, also known as chimney cake due to their shape.



DAREDEVIL STUNTS

We investigate some of the most tyre-smoking, death-defying stunts that seem to fly in the face of physics

Words by **Charlie Evans**

It's hard to watch the incredible vehicular stunts in films such as *Fast and Furious* and *Mission: Impossible* and not imagine being behind the wheel racing through the streets and performing jumps. But stunts are more than just CGI magic; they're the work of professional daredevils who risk their lives for these high-speed performances. For stunt drivers it's not enough to just use their car to cruise down to the beach or drive around town – they want the excitement and danger.

Vehicle stunts first revved up in the 1800s when a telegraph messenger in Connecticut gained fame for the tricks he was performing on his penny-farthing bicycle. He was later credited with the first wheelie on a modern bicycle. Then came the invention of motorbikes and cars,

which soon saw thrill-seekers using their vehicles in ever-more daring ways.

Carnivals started to regularly host groups of stunt riders, or 'stunters', as the sports gained more attention, and by 1915 the 'Wall of Death' was invented. As the name suggests, the new trick had a reputation for being dangerous. With the tracks stood vertically, the idea of the stunt is that bikers start at the bottom of the drum, and as they accelerate they are able to drive horizontally around the inside of the track (a feat we expect is actually as terrifying as it sounds).

Vehicular stunts in cinema started shortly after, with 1958's *Thunder Road* introducing the era of the stunt-heavy car chase, leading to more recent iconic stunts on our screens like the sensational truck flip orchestrated by Chris

Corbould in *The Dark Knight* or the multi-car stunts on the bridge in *Deadpool*.

These aren't the sorts of stunts that people jump into without any planning. Each stunt you see is meticulously practised and calculated, whether in the movies or live stunt performances. The coordinated teams will often first practise with dummies to get a feel of the trick before a stunt driver attempts it properly. They will also use computers to predict the trajectory and calculate speeds and the locations of landings.

The first automobile stunt in cinema history that utilised technology to assist in the planning was James Bond's 360-degree corkscrew in mid-air with an AMC Hornet X in *The Man with the Golden Gun* (1974).

WALL OF DEATH

This death-defying trick is made to look easy by the professionals, but they're battling the laws of physics to complete the stunt

Normal reaction force

The force of the surface of the Wall of Death is pushing against the bike horizontally.

Three forces together

The three forces act together but not across the same line, so balance between the forces (equilibrium) cannot be reached and the bike will naturally begin to experience a turning force (torque).

Leaning to balance

To compensate for this rotation and to balance the forces the biker must lean at an angle, so they are not quite perpendicular to the vertical surface of the wall.

Weight force

The combined weight force of the bike and rider is pulling the vehicle downwards.

Friction force

The frictional force acts upwards on the tyres to balance the downward force of gravity.

A stuntman performs a dangerous trick – standing on top of a moving car that is balancing on two wheels

The cars behind the extreme stunts in the movies have a lot of modifications

behind the scenes that are carefully kept out of view of the camera. They are usually heavily reinforced to protect the driver, with the majority of the car frame replaced with heavy steel that can withstand up to ten crashes. Roll cages are also fitted (and kept just out of shot) to protect both the driver and the vehicle, thereby preventing the sides and roof from crumpling.

More unique stunt vehicle modifications include those made to Australian stunt rider Robbie Maddison's motorbike, which is flanked by two small fins to slightly increase the surface

area of the bike. This means that, providing he doesn't stop or slow down, he can ride across water. His stunts have included hurtling across the surface of the ocean off Tahiti and surfing giant waves on his motorbike.

While professional vehicle stunting started as a movie and carnival industry, today these fearless daredevils take to YouTube and social media, achieving fame by pushing their mind and body to the limits in their chosen vehicle. YouTuber Devin Graham produces some truly breathtaking videos, including wing-walking and skateboarding the steep sides of canyons. You can also find some incredible tricks by biker Sarah Lezito and fearless stuntwoman Jessie Graff. Just like professional stunt videos, these performances aren't without risk.

There is a lot of science behind the precision drifts, canyon jumps and rally ramps that stunt drivers perform, most of which centres around learning how to keep a low centre of gravity, calculate trajectory and projectile motion and design and build modified vehicles.

Stunting requires nerves of steel and complete synchronisation between driver and vehicle while the engines roar and the crowds cheer. But it's the lead up to the stunt that defines its success. The level of skill and command over the vehicle, a strong understanding of physics, and thousands of hours dedicated to training the body are the reason that seemingly fearless performers are able to carry out their stunts successfully, which is why we advise you not to try any of this at home.



Evel Knievel: the life of the greatest stuntman

From an early age, Knievel was destined for stardom

Evel Knievel (real name Robert Craig Knievel) was born 17 October 1938 in Montana, US. When he was eight years old he attended a Joie Chitwood car thrill show, a performance that would inspire Knievel to pursue a career as the most famous daredevil in history.

In 1965 he completed his first real stunt; he attempted to jump over two mountain lions and a crate of rattlesnakes, but he didn't jump far enough and landed on the crate of snakes. Over the next few decades he would build himself a reputation as a vehicle stuntman, attempting over 75 ramp-to-ramp motorcycle jumps.

He became an overnight celebrity after ABC's Wide World of Sports aired one of his biggest disasters. In 1967, Knievel attempted to jump 46 metres – the longest of his career – over the fountains at Caesars Palace in Las Vegas, but fell short and crashed, suffering multiple fractures. More than ten years after his death, he continues to hold many world records, including the most broken bones in a lifetime – 433 in total!

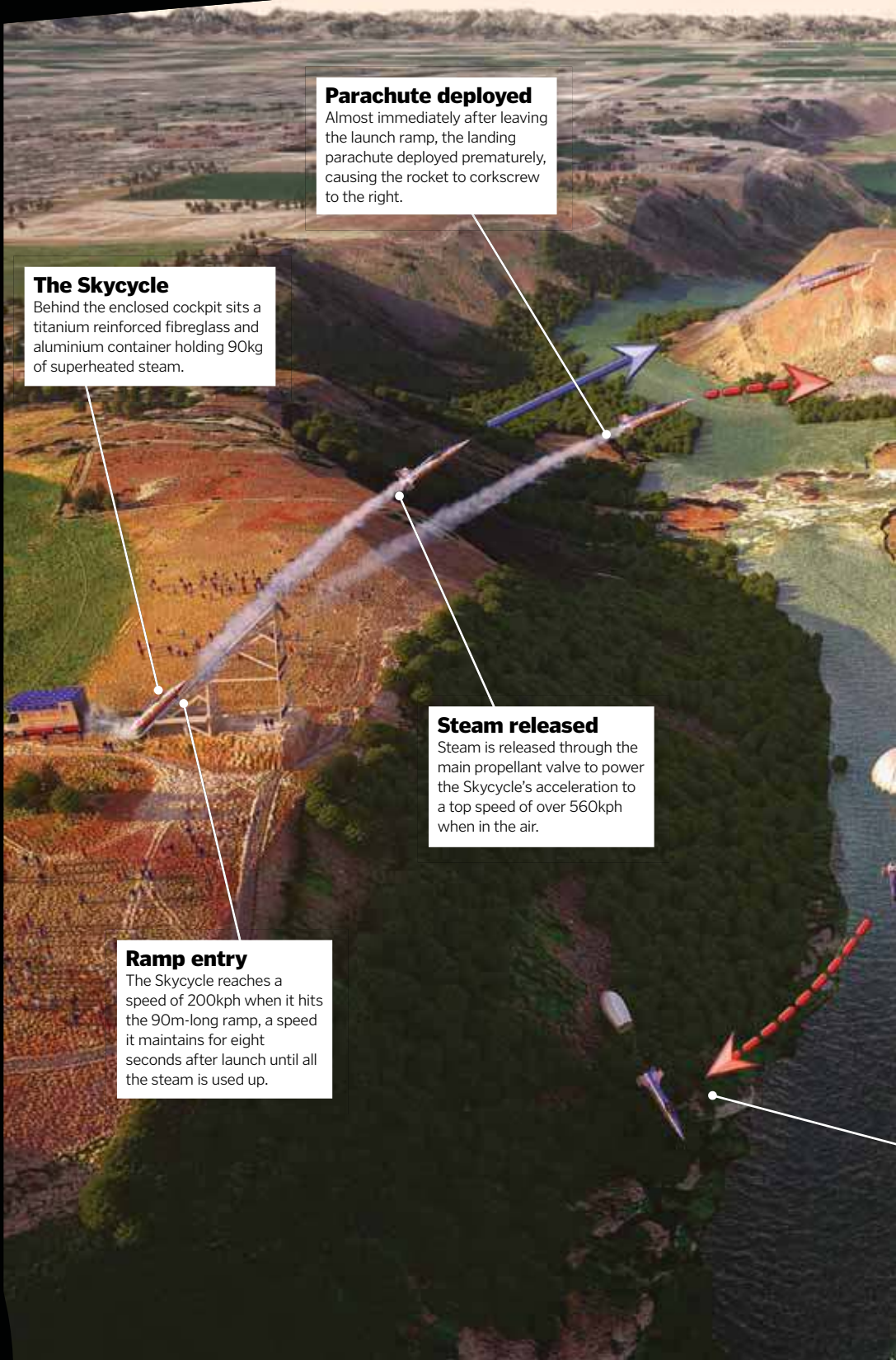


Knievel became a pop culture icon; his failures were often more famous than his successful stunts

JUMPING THE SNAKE RIVER CANYON

Evel Knievel's famous 1974 canyon jump attempt in a steam-powered rocket didn't go to plan, but he managed to escape with his life

■ Planned jump
■ Actual jump



Parachute deployed

Almost immediately after leaving the launch ramp, the landing parachute deployed prematurely, causing the rocket to corkscrew to the right.

The Skycycle

Behind the enclosed cockpit sits a titanium reinforced fibreglass and aluminium container holding 90kg of superheated steam.

Steam released

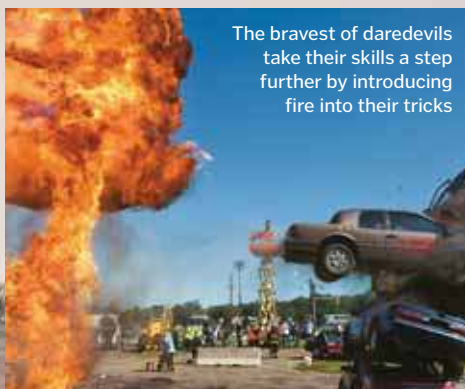
Steam is released through the main propellant valve to power the Skycycle's acceleration to a top speed of over 560kph when in the air.

Ramp entry

The Skycycle reaches a speed of 200kph when it hits the 90m-long ramp, a speed it maintains for eight seconds after launch until all the steam is used up.

Planned trajectory

In the planned stunt, the canopy was meant to blow once the Skycycle cleared the canyon, at which point two parachutes – one attached to Knievel and one attached to the rocket – would open.



The bravest of daredevils take their skills a step further by introducing fire into their tricks



Motocross bikes are a favourite stunt vehicle as their lightweight frames mean they take to the air easily

FIVE OF THE WORLD'S MOST FAMOUS STUNTS

1 Kenny Powers' border jump

Kenny Powers attempted to jump a 1.6-metre section of the St Lawrence River that separates the US and Canada. The Lincoln Continental was rocket powered and fitted with small wings, but it crashed when it was driven off the 26-metre ramp. **FAILURE**

2 The younger Knievel

Robbie Knievel, son of the famous Evel Knievel, attempted a 55-metre jump over 25 pickup trucks when he was 29 years old but was thrown to the ground when he hit the 22nd vehicle after sliding out of control during his approach to the jump. **FAILURE**

3 Team Hot Wheels set world record

In 2011, American stuntman Tanner Foust set a world record when he drove a Pro 2 truck down a vertical Hot Wheels-style track and sailed 101 metres through the air. He removed his mask to reveal his identity after he landed. **SUCCESS**

4 Skydiving from a car over Area 51

Skydivers Konstantin Petrijcuks and Steve Curtis shot to fame in 2017 when they drove a car full of skydivers out of the back of a plane to free-fall to the ground near Area 51 in Arizona, jumping out of the vehicle before it concertinaed into the Earth. **SUCCESS**

5 The xXxTreme-inspired Yarra River Ride

FMX rider Robbie Maddison rode his motorbike along the surface of the Yarra River on 22 December 2016 in Melbourne, Australia, a trick that was originally inspired by a major stunt seen in the movie *xXx: Return of Xander Cage*. **SUCCESS**

Intended landing site

With the parachutes open, Knievel and the Skycycle would have landed safely on the planned landing site.

Crossing the canyon

While Knievel does make it across the canyon, the wind catches the chute and drags him back towards the gorge.

Falling

With Knievel and the bike dangling down from the parachute, the Skycycle sinks to the bottom of the canyon, hitting the rocks. Knievel escapes alive.

"If you fall during your life, it doesn't matter. You're never a failure as long as you try to get up"
– Evel Knievel (1938–2007)



Snow groomers

Discover how these machines help keep the slopes ski-ready

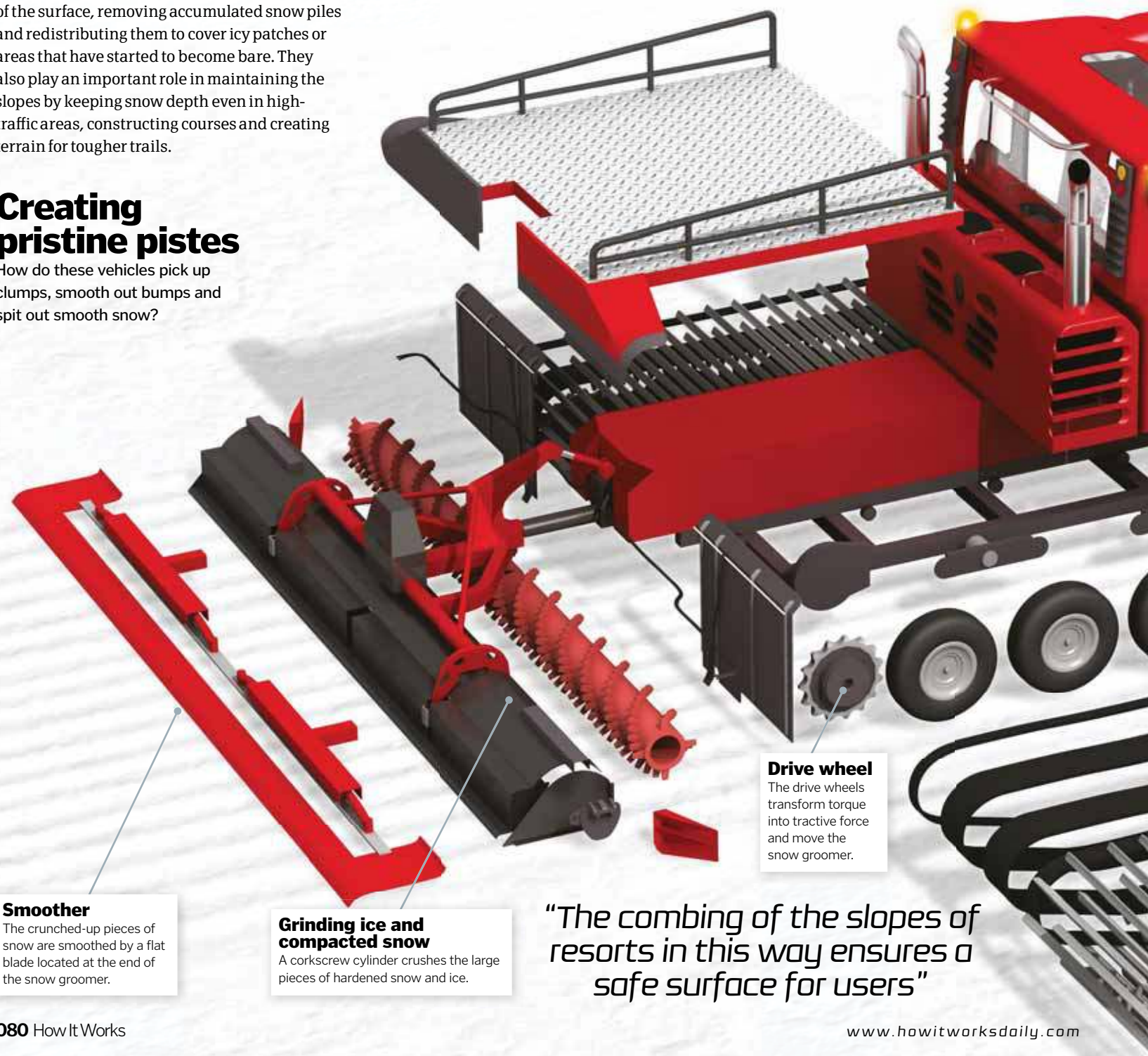
After snowboarders and skiers have packed up their kit and started to head home, it's time for the staff of a snow sport resort to start their daily maintenance. One of the most important tasks is snow grooming; the smoothing of the pistes that is diligently carried out every night. To do this a tractor or truck is normally used to carry specialist towing equipment. They operate by moving, flattening or compacting the snow to improve the condition of the surface, removing accumulated snow piles and redistributing them to cover icy patches or areas that have started to become bare. They also play an important role in maintaining the slopes by keeping snow depth even in high-traffic areas, constructing courses and creating terrain for tougher trails.

Creating pristine pistes

How do these vehicles pick up clumps, smooth out bumps and spit out smooth snow?

The machine runs on two large tracks made from rubber and steel that disperse the weight of the vehicle evenly across the surface. Fitted to the rear is a power tiller that churns the snow before a heavy comb or smoother pulls across the surface. This tiller is responsible for leaving behind the distinctive striped patterns of a groomed slope.

When you see the pistes before hundreds of skiers and snowboarders have taken to the slopes, you will notice lots of thin, uniform lines in the snow. These have been left behind by a snow groomer after the small cogs inside the vehicle have broken up the surface. The combing of the slopes of resorts in this way ensures a safe surface for users every day of the skiing season.



"The combing of the slopes of resorts in this way ensures a safe surface for users"



The lines left behind by a snow groomer are known as 'corduroys'



The steel blades on the caterpillar track of snow groomers help the vehicle climb by digging into the snow and providing grip



Headlights

Headlights are mounted to the front of the vehicle so the snow groomer can be operated night or day.

Front blade

A multi-directional blade cuts and levels the surface of the snow.

Driver

Though easier than driving a car, snow groomer operators must have years of experience to correctly maintain a ski slope.

Guide wheel

The guide wheels offer stability and are responsible for turning the machinery.

Caterpillars with ice thorns

A rubber track with steel blades digs into the snow so the plov can ascend and descend the slopes.

5 FACTS ABOUT SNOW GROOMERS

1 Steep slope groomers
When the gradient of a ski slope is high, snow groomers are attached to a winch and hauled to the top before being slowly lowered in reverse to smooth the snow.

2 Snow farming
Snow farming is a method of strategically manipulating snow coverage (usually by using obstacles or equipment) to create piles that can be redistributed by snow groomers.

3 Piste basher
Snow groomers are also known as snow smoothers, snowcats, or in some places they are informally known as 'piste bashers'.

4 Other purposes
Because snow groomers are lightweight they are also used in agriculture and for work on peat bogs and biogas sites.

5 The first snow groomer
The first patented snow groomer was invented by Stephen Bradley in March 1957 for grading and packing snow.

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Musher

The musher calls out commands to the dogs to guide the team, either standing or running and pushing the sled to give it a boost of speed.

Basket sled

The sled carries belongings and equipment in a basket raised from the ground to reduce friction and make it more manoeuvrable.

Wheel dogs

The strongest of the pack are the wheel dogs, and they play the biggest role in pulling the sled.

Lead dogs

The most trusted and experienced dogs lead the team and respond to the musher's commands to set the pace and turn in the right direction.

Team dogs

The team dogs provide most of the power required to pull the sled, and larger teams may have several pairs of team dogs.

Swing dogs

Swing dogs are responsible for ensuring the sled team follow the turns made by the lead dogs.

The dogsled team

Each dog has a specific duty to keep the canine convoy moving across the snow

Dogsleds

This traditional form of transport can tackle even the snowiest terrain

Over 9,000 years ago, people in northeastern Siberia started selectively breeding dogs for size, strength and stamina that were able to pull sleds over long distances. These teams of dogs were used for transport and became a vital link between dispersed communities.

Today, sledding is still practised around the world from Canada to Lapland, and it has even become a competitive sport. Modern sled dogs

are all about speed and endurance, and a variety of breeds are used for sport, including Alaskan huskies, Samoyeds and Canadian Eskimo dogs. These tough canines have an efficient gait and webbed paws and can pull a sled and its driver at speeds of over 30 kilometres per hour.

To train a dog to sled, the musher has to teach them directional cues. These are taught by first asking the dog to sit behind the trainer, then using a treat to guide the dog forward between the trainer's legs. The trainer moves the treat to one side and calls out the appropriate command word – usually 'gee' to go right or 'haw' to go left. As the dog turns, it's rewarded with the treat.

The next stages of training involve teaching the dog to pull the sled, which is done by running with them until they start naturally taking the lead. Once the harnesses are attached to the dog and the sled, the musher will use a helper to walk or run with the dogs while they call out the commands they learnt previously. The helper will then reward the dog with a treat.

Your dog at home might not be made for sledding, but you can still use these methods to teach them to respond to directional commands when you're going out for a walk.



Dogsledding offers a form of transport by which some of the world's most remote areas can be accessed

Denmark's Sirius Sled Patrol

Denmark owns a truly unique military unit – the world's only military dogsled team. Called the Sirius Patrol, the unit patrols Danish-owned land in the wilderness of Greenland. The unit consists of six dogsled teams, each of which are led by two people and up to about 14 dogs. The teams carry up to 500 kilograms of supplies, including rifles, a radio, sleeping bags and a lot of dog food.

The Sirius Patrol battles blizzards, extreme temperatures (the lowest recorded temperature is -55 degrees Celsius) and isolation as they travel across the frozen Arctic, covering up to 64 kilometres of Danish territory in a day. It's not easy work – in winter the Sun disappears for two months, and the area is plunged into darkness – but the teams work diligently to police the area and support visiting researchers and tourists.



Each patrol lasts around four months, without any human contact outside of the team pair

BRAIN DUMP



Because enquiring minds need to know...

Molecules in alien atmospheres absorb certain wavelengths as light passes through

MEET THE EXPERTS

Who's answering your questions this month?



JODIE TYLEY



TOM LEAN



LAURA MEARS



JAMES HORTON



JO STASS

How can we tell what exoplanets' atmospheres are like?

Shaun Warren

■ Scientists use a technique called transit spectroscopy to examine an exoplanet's atmosphere. When distant planets pass in front of their star, light shines through their atmosphere on its way to Earth. As the light passes through the gas, different atoms absorb different wavelengths. By looking at the difference between the light from the star and the light that passed through the gas we can see which wavelengths are missing. This tells us which molecules are present in the atmosphere. **LM**

Want answers?

Send your questions to...

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How do erasers remove pencil marks?

Tori Clifton

■ When you rub an eraser on a piece of paper you create friction, which causes heat. This heat helps the eraser to become sticky and pick up the particles of pencil graphite from the page. **JS**



Do plants know they're being eaten?

Winnie Jackson

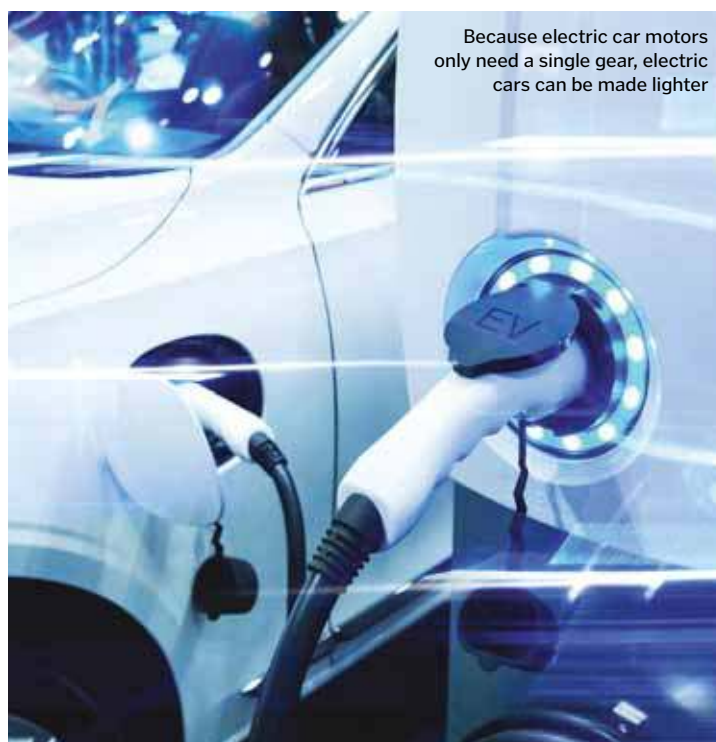
■ There's evidence to suggest that plants respond to hungry caterpillars. When scientists played the sounds of these critters munching on leaves, they found the plant released mustard oil, a chemical that's toxic to caterpillars. **JT**



Do electric cars have gears?

Mandy Hicks

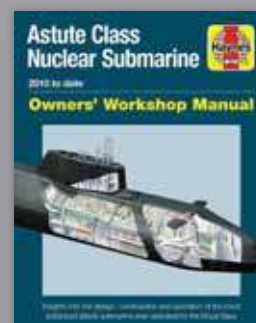
■ Petrol engines only work well when running at particular speeds and produce very little force (torque) when they are running slowly. This means petrol cars wouldn't work properly without gears to manage the power output of their engines, but electric motors don't have these problems. They work efficiently running fast or slow and produce a lot of torque even when running at only a few revolutions per minute. So electric cars only need one gear. **TL**



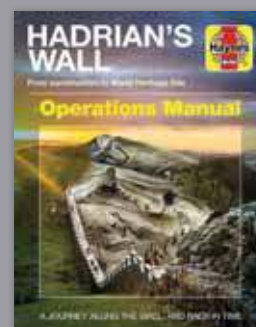
Because electric car motors only need a single gear, electric cars can be made lighter



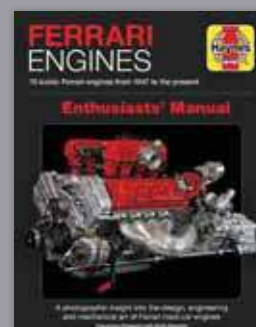
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Why can't we just throw all our landfill waste into a volcano?

Olivia Michaels

■ Lava is around 1,000 degrees Celsius, so it could melt a lot of our rubbish away. However, transporting trash to volcanoes would be costly, melting waste would release toxic fumes, and the remnants of our rubbish would still build up beneath the ground. Cold trash hitting a hot lava lake could also cause dangerous explosions. **LM**



Do stainless steel 'soaps' get rid of cooking odours?

Donna Marcus

■ Stainless steel contains chromium, which is what makes it less likely to rust or stain. Chromium forms an oxide layer when in contact with air and water, and this attracts the smelly sulphur-containing chemicals on your hands from foods like garlic and onion, but researchers are still investigating how well this works. **JT**

Emotions can strengthen memory



Why can I remember song lyrics for so long?

Sarah Ross

■ The average human brain contains about 86 billion neurons – a vast network that processes information. Memories are formed when specific connections between neurons are strengthened, making it easier for you to recall information again and again. Emotions enhance these pathways, and music can often trigger how we were feeling when we listened to it. Our brains also like sound patterns, and songs often use repetition and rhyme – it's how ancient peoples used to remember stories long before the introduction of written language. So whether you loved or loathed a song, chances are you'll still be able to sing along years later. **JT**



How do we know that Earth's magnetic field flips?

Lei Hsiao

■ When lava cools into rock, metal oxides within it are solidified into the orientation of the Earth's magnetic field at that time. By comparing metal oxides in rocks formed at different periods in the Earth's history we can see the planet's magnetic field changed many times over millions of years. **TL**

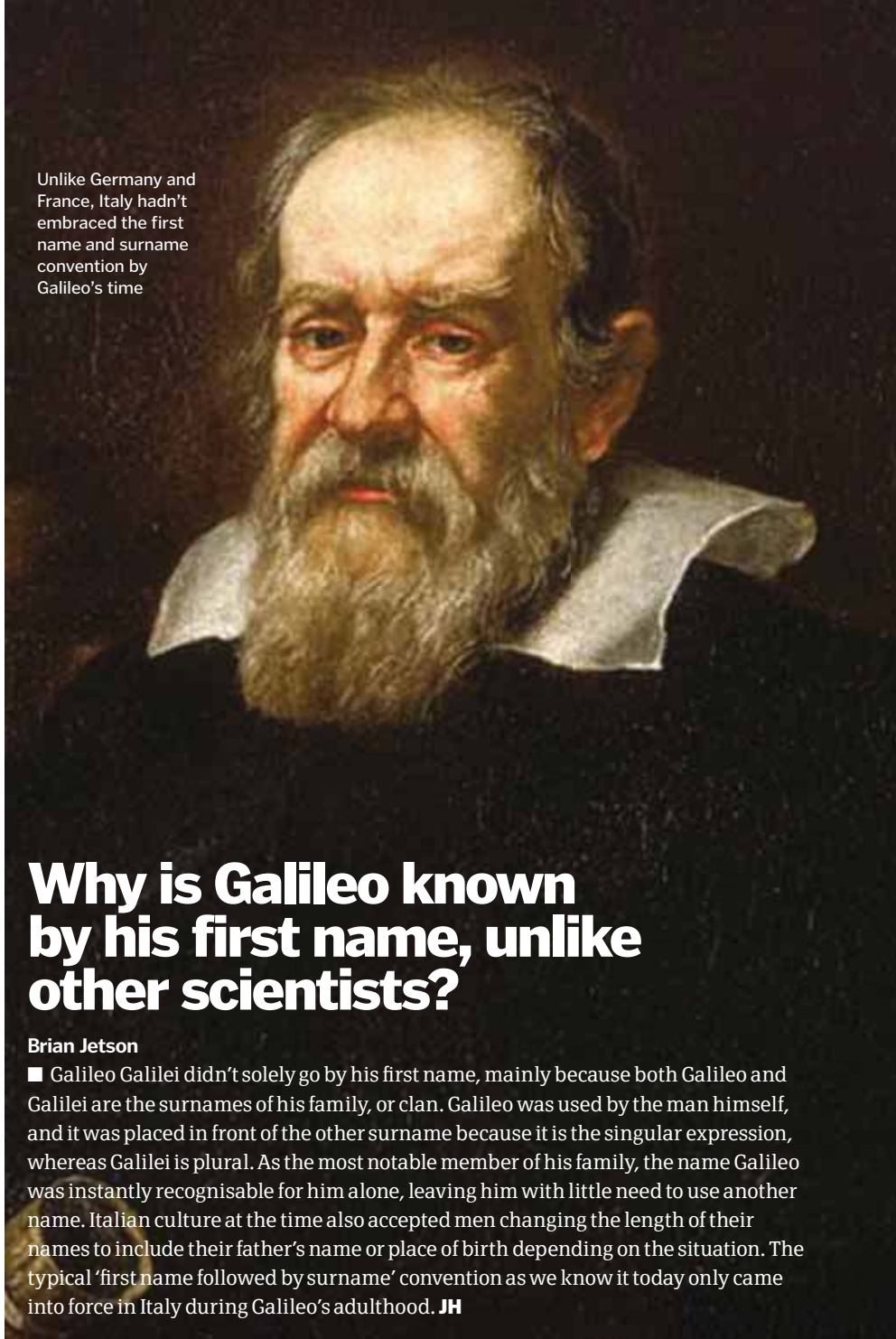


Why do we forget dreams so quickly?

Yusef Demsas

■ Scientists have several theories as to why we forget dreams. Much of our dreaming occurs during REM sleep, a deep period of sleep in which our bodies behave differently to when we are awake. In REM sleep the systems for making new memories don't seem to work as well, which is why people who wake up from dreams recall them better, as there is a chance for them to pass into waking long-term memory. Our brains are good at filtering out non-essential information to concentrate on more important things, so perhaps most dreams just aren't important enough to remember. **TL**

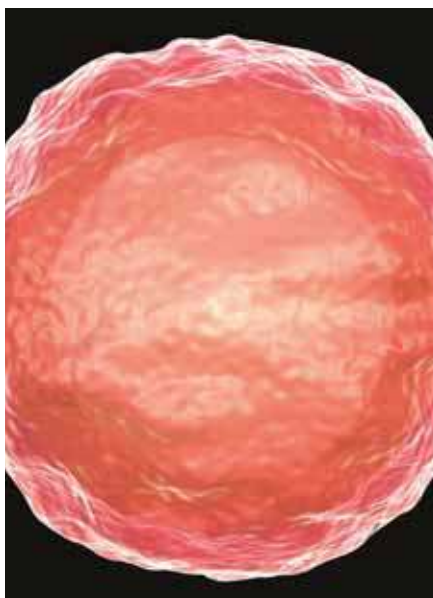
Unlike Germany and France, Italy hadn't embraced the first name and surname convention by Galileo's time



Why is Galileo known by his first name, unlike other scientists?

Brian Jetson

■ Galileo Galilei didn't solely go by his first name, mainly because both Galileo and Galilei are the surnames of his family, or clan. Galileo was used by the man himself, and it was placed in front of the other surname because it is the singular expression, whereas Galilei is plural. As the most notable member of his family, the name Galileo was instantly recognisable for him alone, leaving him with little need to use another name. Italian culture at the time also accepted men changing the length of their names to include their father's name or place of birth depending on the situation. The typical 'first name followed by surname' convention as we know it today only came into force in Italy during Galileo's adulthood. **JH**



Can bacteria survive in space?

Hikaru Koizumi

■ Amazingly, yes. No matter how well scientists scrub and sterilise their satellites, pesky microbes are persistently found aboard the ISS – having survived the vacuum of space to get there! Not all bacteria can accomplish this though; only certain spore-forming bacteria, which can cover their cells in a protective protein layer, can endure the harsh conditions. The hardness of bacteria is impressive but presents serious problems for our exploration of other worlds, as we may accidentally bring some of our own living contaminants along for the ride. **JH**



Why is the Sahara hotter than the equator?

Peter James

■ The equator receives the most sunlight, so it's natural to assume that it would be the hottest place on Earth, but sunshine isn't the only thing that affects temperature. Water is Earth's natural coolant, and oceans, clouds and rainfall around the equator help to keep temperatures down. When there is moisture in the ground, heat turns the liquid to gas and energy escapes into the air. Deserts like the Sahara might get fewer daylight hours, but the ground is so dry that the heat has nowhere to go. **LM**



Could any alternative rocket fuels replace current propellants?

Richard Tucker

■ Scientists are developing less hazardous propellants to replace hydrazine, but switching is complicated. New fuels need rigorous safety testing, and engineers may also need to design new tanks and new rockets to use them. **LM**



Do airport travelators speed you up or slow you down?

Tony Henderson

■ Moving walkways help tired travellers get from A to B in large airports, but not very quickly. Research suggests that we naturally slow our pace because our eyes and legs are getting mixed signals – we think we're going faster than our legs are taking us. The overall time gained is 11 seconds from a 100-metre walkway, but because there are often blockages caused by people slowing down, it could actually be faster to walk unaided. **JT**



Which is the most powerful supercomputer in the world?

Ben Olson

■ The IBM Summit is currently the world's fastest computer. Occupying two tennis courts' worth of floor space and boasting 37,000 processors, the Summit is capable of making 200 quadrillion calculations every second! **JH**



Why do words look or sound weird if we write or say them repeatedly?

Carly Willis

■ The name for this psychological phenomenon is semantic satiation, and it's caused by a type of fatigue called reactive inhibition. When a brain cell fires, it takes more energy to fire a second, third and fourth time. Therefore, the more you say or read a word, the more energy it takes for your brain to recall its meaning. Eventually, it will start resisting thinking of a meaning altogether. This effect is reduced with words that are strongly connected to emotions or have dramatic connotations, such as 'explosion', as the brain can associate them with a different meaning at each repetition. **JS**

Why can't you reach the end of a rainbow?

Franki Coleman

■ A rainbow is an optical illusion, not a physical object, so it doesn't have a physical end point. Seeing a rainbow depends on the position of your eyes in relation to the Sun, so as soon as you start moving towards what you think is the end of the rainbow, it will move out of reach or disappear completely. It's a bit like trying to walk to the end of your shadow; it will move as you do. **JS**

Seeing a rainbow depends on the angle at which sunlight hits raindrops in the sky

Want answers?

Send your questions to...

f How It Works magazine
t @HowItWorksmag
@howitworks@futurenet.com



Why does reading make you sleepy?

Elisa Holme

■ Many of us snuggle up with a book toward the end of the day, when our bodies are already tired. Fatigue coupled with the fact we typically read in a comfortable and relaxed position and that reading requires concentration and lots of eye movement results in tiring us further and helping to send us into a snooze. **JH**



How do cats retract their claws?

Gabriel Ramirez

■ A cat's claws are fixed directly onto bones called distal phalanges – their equivalent of the tips of our fingers. These are connected to other bones in the cat's paw by ligaments and tendons that, when relaxed, keep the claws tucked in, and when tensed, extend the claws outwards. **JS**

Why does spinach make your teeth feel funny?

Kiara Darke

■ Spinach contains high levels of oxalic acid, a natural chemical that reacts with calcium in saliva to produce tiny crystals, which coat your teeth and give them that chalky feeling. **TL**



BOOK REVIEWS

The latest releases for curious minds

Why Can't I Feel the Earth Spinning?

Your biggest science questions answered

- Author: **James Doyle**
- Publisher: **Thames & Hudson**
- Price: **£12.95 / \$19.95**
- Release date: **Out now**

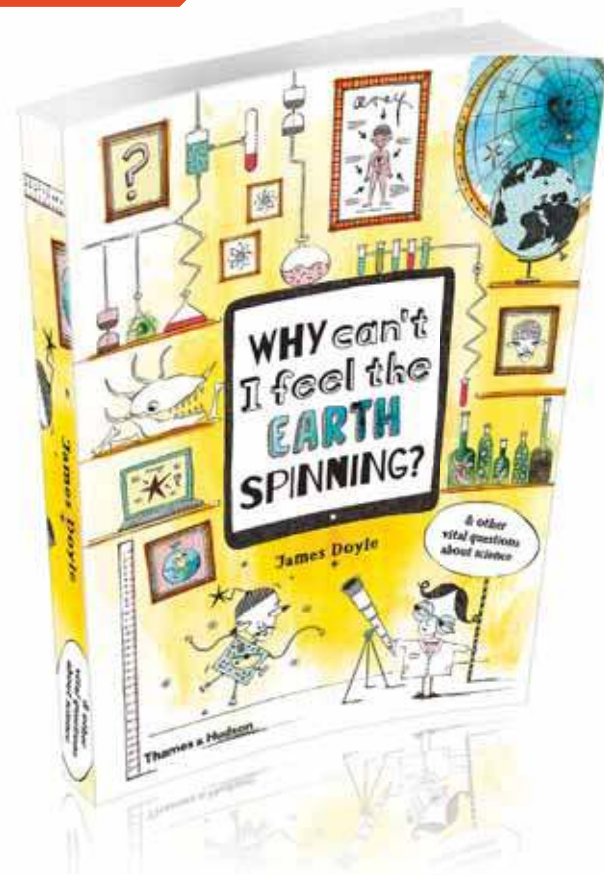
Science is, at its core, all about questions. How did we get here? Why does that thing work the way it does? What happens when I do *this*? This book asks some of the bigger questions that kids might have, and it answers them in a fun, insightful way.

There are 22 of these 'big' questions covered – each one has two full spreads dedicated to it. The first spread answers the main question, alongside quirky, engaging illustrations and images. Then the second spread asks – and answers – follow-up questions that readers might have. These aren't too complex, so this is probably one for slightly younger scientific

minds. For example, one spread asks why medicine tastes so bad then follows up with questions about deadly plants and the reasons we can't eat mould. That said, the answers are always interesting, and there's bound to be something on every page that's of interest.

Some of the questions are inspired, and it's clear that the author really understands how children think as he asks such questions as why do stars twinkle? While reading the answer, we learned what the phrase stellar scintillation meant. If we can be surprised by this book, kids will absolutely love it.

★★★★★



The Atlas Obscura Explorer's Guide for the World's Most Adventurous Kid

A beautiful way to travel the world from your chair

- Author: **Dylan Thurais and Rosemary Mosco**
- Publisher: **Workman Publishing**
- Price: **£14.99 / \$19.95**
- Release date: **Out now**

Everyone has seen an atlas, or taken a trip around the globe with Google Maps looking at some of the most popular cities and tourist spots, right? You can fly from the Golden Gate Bridge to Moscow's Red Square without leaving your house. But those aren't the world's most adventurous locations, which is why this book is so much fun.

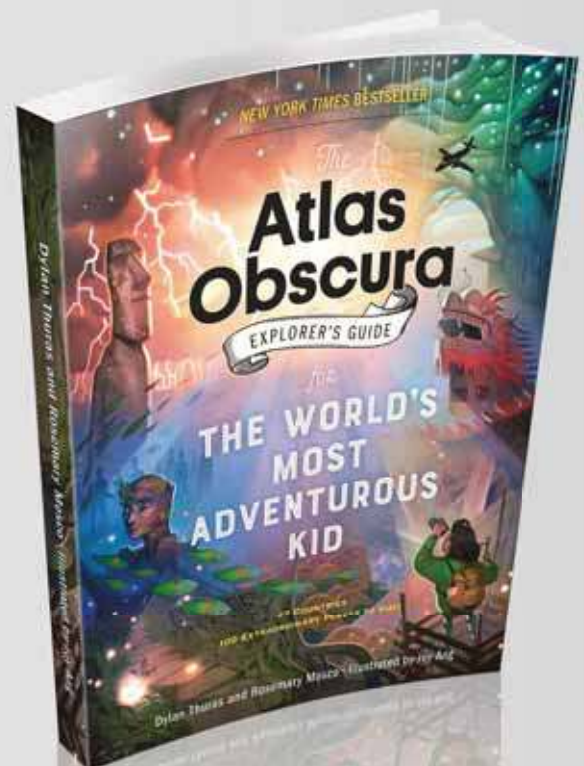
Atlas Obscura takes you on a trip to the world's lesser-known locations; points on the map that contain incredible wonders, forgotten treasures, or creepy places. Each one is beautifully illustrated by Joy Ang, with children often present as exploratory guides. The drawings bring it all to life, while the authors' descriptions help readers understand what each one holds.

"After reading this we spent ages browsing some of the locations online"

For us, the best part is that each page includes a longitude and latitude. Type these into Google Maps and you can see these amazing places from the sky or – if you're lucky and someone has shared their photos – from inside.

After reading this we spent ages globetrotting online, seeing some of the amazing places mentioned in the book. It's inspiring, so don't be surprised if you end up longing to visit some of them for real.

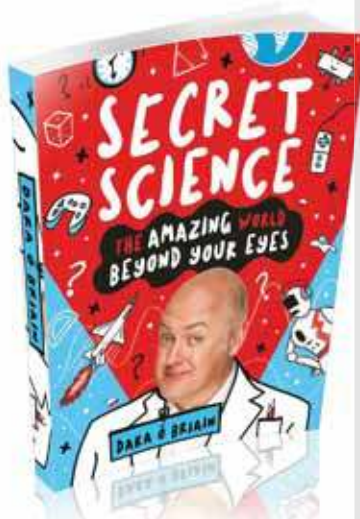
★★★★★



Secret Science: The Amazing World Beyond Your Eyes

Right there in front of you

- Author: **Dara Ó Briain**
- Publisher: **Scholastic**
- Price: **£12.99 (approx. \$17)**
- Release date: **Out now**



Let's usher the elephant out of the room: yes, Dara Ó Briain has written a science book. It isn't even his first one. But is it any good?

Aimed primarily at children, the TV funnyman (also a maths and theoretical physics graduate, by the way) channels his endearing wit in a winning fashion, encouraging his readers to look beyond the everyday and consider exactly what drives everything in front of them. From everyday functions like eating and sleeping to the seasons

and what allows airplanes to fly, he has an answer for everything, although the questions aren't what you might expect: why stroking your cat makes you more stressed, or why your brain is waiting for a tiger to eat you, for example.

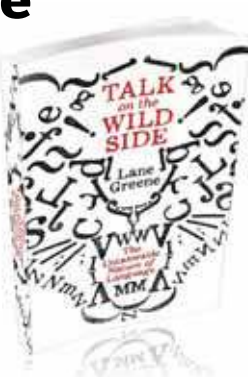
Presented in a large, dynamic font and with numerous illustrations sprinkled throughout, this does its job well, proving to be a worthy entry point into the science gateway.

★★★★★

Talk on the Wild Side: The Untameable Nature of Language

Communication is the key

- Author: **Lane Greene**
- Publisher: **Profile Books**
- Price: **£14.99 / \$26**
- Release date: **Out now**



As long as we can remember, *The Economist* has always been linked with rigorous analysis and high-quality written output, which is why we fully trust this book from Lane Greene, its author of the Johnson column on language.

Happily, it also relishes making fun of grammar sticklers - admittedly this writer is one of them, but still. Looking at language as the constantly evolving and expanding phenomenon that it is, *Talk on the Wild Side* is both

analytical and engaging in its approach, examining both popular culture and scientific process during its hypothesis and investigation. Refreshingly, it doesn't come across as at all stuffy, which is

another positive characteristic of *The Economist*.

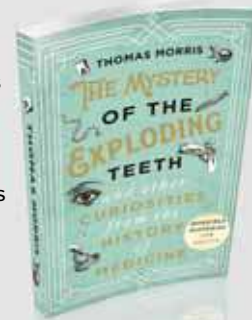
Inevitably, such an in-depth look at language will have its limitations in terms of wider appeal, but we'd recommend giving it a try. Books that break down potentially tricky subject matter in such a manner are hard to come by, so this one should be treasured.

★★★★★

The Mystery of the Exploding Teeth and Other Curiosities from the History of Medicine

Believe it or not, the title actually undersells it

- Author: **Thomas Morris**
- Publisher: **Bantam Press**
- Price: **£14.99 / \$26**
- Release date: **Out now**



Described on the cover as 'Horrible Histories for adults', Thomas Morris' new book is immediately given a lot to live up to.

Admittedly, by calling his first chapter 'A fork up the anus', he makes a pretty decent fist of doing so. After all, how can you not read on after that?

Galvanising this readerly good will, Morris proceeds to detail a whole host of maddening medical case studies. Not all of them are as eye-watering as the opening chapter

(even though some seem to have been beamed straight out of *Brass Eye*, notably 'The boy who vomited his own twin'), but each of them retains his gift for keeping you transfixed. Stylistically he recalls

Bill Bryson, such is the pure compulsiveness of his fact-infused prose.

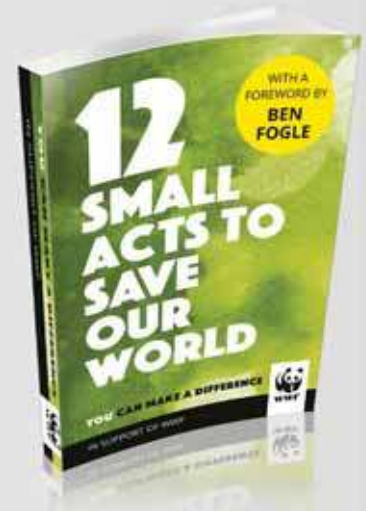
Honestly, we can't remember the last time we enjoyed reading a science book so much. It may not teach you everything you want to know, but it'll definitely regale you with a number of things you won't ever forget.

★★★★★

12 Small Acts to Save Our World

Earth in crisis

- Author: **WWF**
- Publisher: **Century**
- Price: **£12.99 (approx. \$17)**
- Release date: **Out now**



With the United Nations' scientific advisory board recently issuing a startling warning that unprecedented co-operation between all of the world's major powers will be needed to avert potentially dire consequences, the timing of this book couldn't have been anymore apt.

While it's looking unlikely that the world's leaders are going to take much notice any time soon, there's no reason why we as individuals can't act. Handily, the WWF is here to tell us what we can do to help. From switching off household appliances when they are not in use

to moderating the amount of meat that we eat, some pretty straightforward little steps can add up to a very big difference.

Yes, it may at times feel like a lecture you've already heard hundreds of times before, but all things considered, maybe it's one that we really do need to hear. After all, we only get one planet; time to start looking after it better.

★★★★★

Wordsearch



FIND THE FOLLOWING WORDS...

CHANDRAYAAN
CHOCOLATE
CONSERVATION
DAREDEVIL
DOGSLED
FESTIVE
MARKETS
MOONS
RAINBOW
REINDEER
SNOW
STAR
TEDDY
TINSEL
VATICAN
WHATIF
WINTER
WREATH

Quickfire questions

Q1 Who was the third member of Apollo 11 alongside Armstrong and Aldrin?

- ☐ James Lovell
- ☐ David Scott
- ☐ Eugene Cernan
- ☐ Michael Collins

Q2 Which is the best-selling Christmas single worldwide?

- ☐ Last Christmas - Wham!
- ☐ Do they know it's Christmas? - Band Aid
- ☐ White Christmas - Bing Crosby
- ☐ All I want for Christmas is you - Mariah Carey

Q3 What's 'sod's law' also known as?

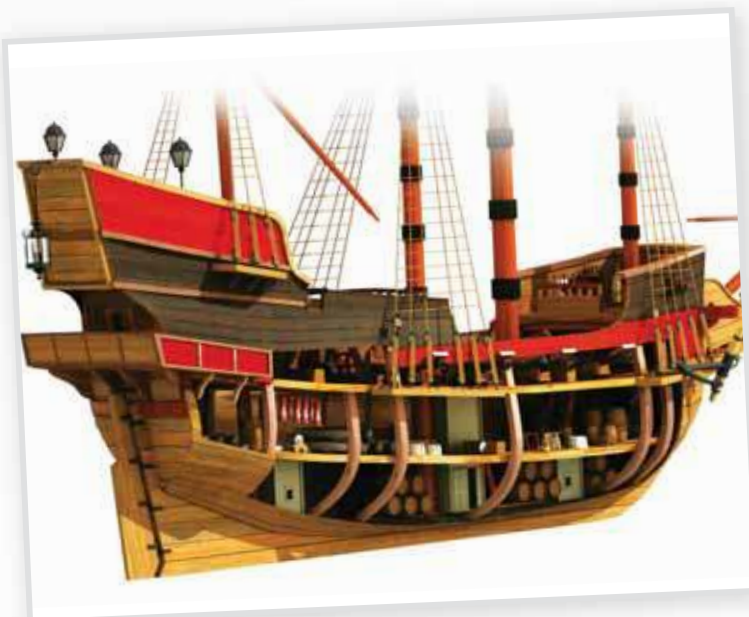
- ☐ Murphy's law
- ☐ Nature's law
- ☐ Moore's law
- ☐ Occam's razor

Q4 The Great Wall of China is visible from the Moon

- ☐ True
- ☐ False

Spot the difference

See if you can find all six changes we've made to the image on the right



Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

		7		6	8	2	5	4
	6	8				1	3	7
		4	1	3	7			
7	5	6		2		3	1	8
8		3	6	7	5	9		2
4			8	1	3	5		
		9	7			6	2	5
	7	5		9	6			1
	8		2	5	4	7	9	

VERY DIFFICULT

			2				7	1
		2				9	4	
	4	1		8	3			5
1			9	2				
	9	8						3
	6		4	3	8			
7							1	
4					2			
8					6	7		9

What is it?

Hint:

It was the world's tallest man-made structure until New York's Chrysler Building was finished in 1930

A

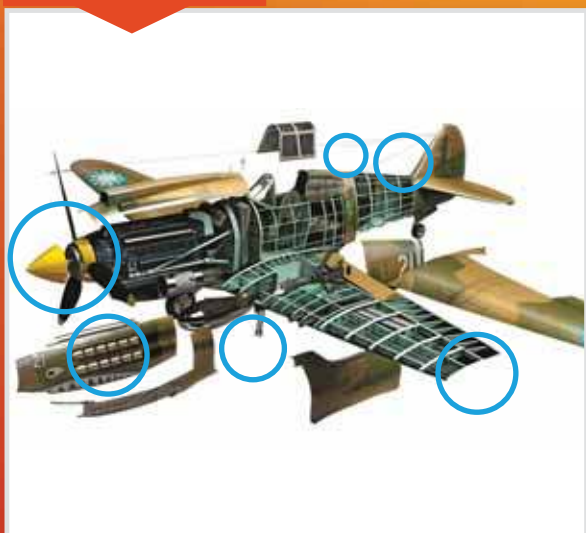


For more brain teasers and to test your problem-solving abilities, enjoy our *Mensa Puzzle Book*, which is packed with challenging problems and puzzles designed by experts.

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Spot the difference



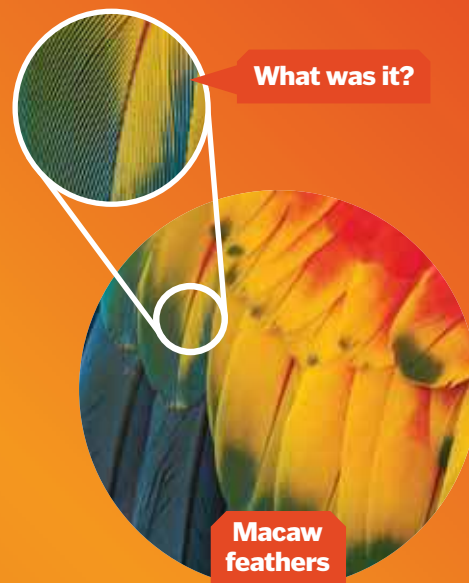
Check your answers

Find the solutions to last issue's puzzle pages

Quickfire questions

- Q1** 15 November 1605
- Q2** Fanta
- Q3** Chimborazo
- Q4** 12

What was it?



Macaw feathers

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Make a festive wreath

Create a decorative door hanging for the holiday season with this simple guide

**DON'T
DO IT
ALONE**

IF YOU'RE UNDER
18, MAKE SURE YOU
HAVE AN ADULT
WITH YOU



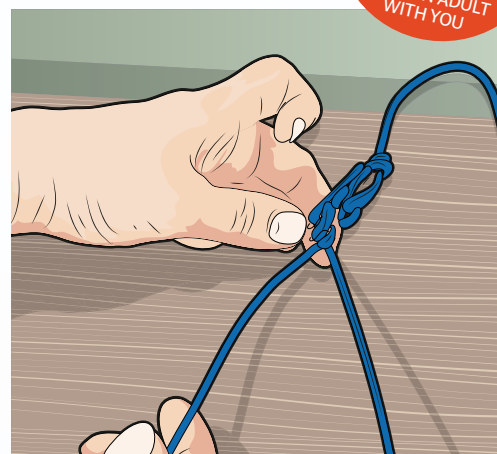
1 Gather your materials

You'll need some evergreen clippings (try cedar and pine), decorations (berries, holly leaves and small pinecones), floristry wire and a long red ribbon. For the base, you can buy a ready-made frame or make your own with a wire coat hanger.



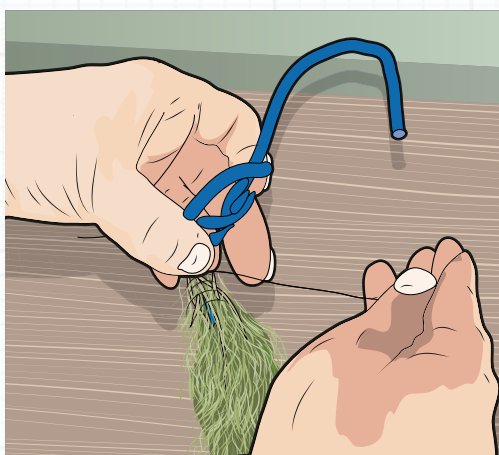
2 Do it yourself

If you have a ready-made base, skip to step 3. To create your own base, carefully shape your coat hanger into a circle. It might help to wrap it around another curved object to help smooth out any corners more easily.



3 Begin assembly

Attach one end of the floristry wire to the top of the frame. Wrap it around the spot you've attached it a few times, then twist or tie it to make sure that it remains fixed in place. Don't cut the wire yet.



4 Attach the greenery

Take one small bunch of your evergreens (you can clip the bundle if it's too bulky), hold its 'branch end' where you've attached the wire and wrap more wire around the branch and frame at least three times to fix it in place.



5 Keep going

Take another bunch and this time tuck its branch end under the tips of the bunch from step 4, then wrap the wire around the stems of each bunch. Repeat until the circle is complete. Secure the wire around the last bundle, tie it off and cut it.



6 Finishing touches

With new pieces of wire you can attach decorative elements like berries and pinecones around your wreath. Loop your ribbon around the top and tie it in a bow to finish. Now the completed wreath is ready to hang on your door!

BEFORE YOU BEGIN...

Make sure you have permission to take clippings of trees and berries, or better yet try to use some that have already fallen. If you're under 18 ask an adult to help – some branches may be tough and require garden clippers to chop into smaller bundles.

Had a go? Let us know! If you've tried out any of our experiments – or conducted some of your own – let us know! Share your photos or videos with us on social media.

Disclaimer: Neither Future Publishing nor its employees can accept any liability for any adverse effects experienced during the course of carrying out these projects or at any time after. Always take care when handling potentially hazardous equipment or when working with electronics and follow the manufacturer's instructions.

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How could we travel back in time?
Are wormholes the answer?

Letter of the Month

Travelling to the past

Dear HIW,

For a while now I have been dying to find the answer to this question: is it possible to go backwards in time? I know for a fact that as an object goes faster, the speed that time goes inside that object is slower relative to the world around it. Basically, according to my knowledge, this will always result in the same 'area', but each factor of space and time will be different. So, in principle, doing this in reverse to go back in time, wouldn't you need to have negative speed? Thank you guys so much for reading this question and have an amazing day!

Evan Zhang

Time travel is definitely a head-scratcher when you try and understand the theoretical physics behind the idea. The most explored concept of time travel centres around the theory of wormholes.

Space and time are both said to be interlocked and distorted or curved by mass. Objects with a tremendous amount of mass

could potentially bend the fabric of space-time to such an enormous extent that a tunnel or wormhole would be created as a result, thereby connecting two separate areas of space-time that may be billions of lightyears apart from each other.

If it were somehow possible to travel through a wormhole to reach the other side, you would have created a cosmic shortcut, effectively time travelling by crossing the universe at a much faster speed than a beam of light would go if it was travelling normally from A to B.

An exciting experiment conducted at the University of Barcelona in 2015 saw scientists engineer a tiny magnetic wormhole that enabled a magnetic field to disappear at one end of the tunnel before reappearing at the other. However, the idea of wormholes in space and whether we will ever time travel are both still very much theoretical concepts.

WIN!

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Exercise boost

Dear HIW,

I was feeling really tired today and I hadn't done much, but when I started to exercise a bit more I actually felt less tired. Is there a reason for this?

Will Everitt

It's something we have all felt at one time or another, perhaps after a long day of binging a new TV series, for example, which can cause us to feel just as tired as when we first woke up. But you're correct, exercising can boost your energy levels. When we exercise we release endorphins, a natural hormone that boosts energy, along with mood-enhancing neurotransmitters such as dopamine. It may seem counterintuitive to expel energy in order to feel like you've gained it, but going for a jog if you're tired can give you a great boost.



Dreams without vision

Dear HIW,

I have been wondering, do blind people dream, and if so, which colours do their dreams contain?

Gabriel Stevens

There have been a few studies on this. One compared the dreams of congenitally blind (CB) patients and patients who became blind in later life (LB) alongside a control group. It found the CB patients experienced dreams more so with other senses such as sound and touch when compared to the control group, whereas LB patients still maintained visual dreams, though this was relative to the amount of time before becoming blind. As time passes these visual dreams become less likely.

The truth about tonic water

Dear HIW,

I was wondering, what exactly is tonic water and was it once used as an actual tonic?

Thanks,

Steph Fox

It is in fact true that tonic water was once used as a tonic to help prevent malaria. Tonic water in its simplest form is water, carbon dioxide and quinine. It is the quinine addition that protects against malaria as it is thought to be toxic to the Plasmodium parasites that cause the disease. It's also the substance that gives tonic water its bitter taste. However, when it was a tonic the doses were not as diluted as modern bottles, and during the 1800s it was paired with gin to make it more palatable.



Tonic water glows under UV light due to the quinine within it

Roman winter

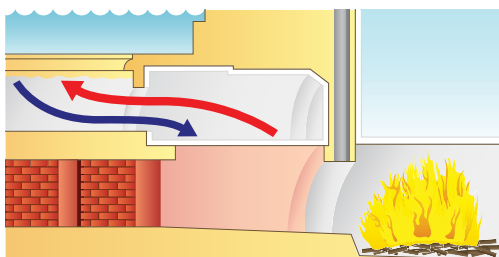
Dear HIW,

How did the Romans, especially those living in Germany and England, heat their large homes during the cold seasons?

Thanks,

Naomi Littler

In order to heat their homes, Romans used large underground heating constructions called hypocausts. This early under-floor heating system vented hot air from a furnace or fire through passages to vents in different rooms thereby warming the whole building.



The Romans created underground heating to keep warm during winter

www.howitworksdaily.com

What's happening on...

social media?



This month, we asked you to send in your thought-provoking "What if...?" science scenarios

"What if John Logie Baird or Alexander Graham Bell hadn't invented stuff? .."

@manda39

"What if there were no gravity?"

@2Shelley09

"What if we woke up one day and we could understand what animals were saying?"

@positiverachel8

"What if we discovered the end of the universe? What would be beyond it?"

@naynayeams

"What if birds aren't really singing and are screaming because they are scared of heights?"

@danigraves87

"What if it is all just an illusion and we are an experiment in a petri dish?"

@twit_tweeter

"What if all the seas and oceans and rivers dried up?"

@greigo_uk

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FAST FACTS

Amazing trivia to blow your mind

SNOWFLAKES ARE TRANSLUCENT AND DIFFUSE THE ENTIRE VISIBLE LIGHT SPECTRUM TO APPEAR WHITE

MICHAEL JACKSON'S *THRILLER* (1982) REMAINS THE BEST-SELLING ALBUM OF ALL TIME, WITH OVER

66 MILLION
COPIES SOLD WORLDWIDE

CHANDRAYAAN-2 WILL BE THE FIRST LUNAR MISSION TO LAND SO FAR FROM THE MOON'S EQUATOR

DAREDEVIL EVEL KNIEVEL BROKE

433
BONES IN HIS LIFETIME

EUROPA COMPLETES AN ORBIT OF JUPITER EVERY

3.5 EARTH DAYS

THE VATICAN MUSEUMS ATTRACT OVER

6 MILLION
VISITORS A YEAR

OVER 26,000

SPECIES ON THE IUCN RED LIST ARE THREATENED WITH EXTINCTION

IN DECEMBER, UK HOUSEHOLDS SPEND

+20% ON FOOD

+30% ON ALCOHOL

+80% ON BOOKS

COMPARED TO THE REST OF THE YEAR

IT TAKES AN ENTIRE YEAR'S CROP FROM A SINGLE *THEOBROMA* CACAO TREE TO MAKE A SINGLE 450-GRAM CHOCOLATE BAR

THE IDITAROD TRAIL SLED DOG RACE IN ALASKA, US, IS THE LONGEST IN THE WORLD AT

1,688 km

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